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Conservation Education: Using Birds to Connect Communities to their Natural Environment

Kathryn A. Olson
University of Montana, Missoula, ko127157@umconnect.umt.edu

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By Kat Olson, Environmental Studies MS 2019

The theme of my portfolio is conservation education, using birds as an example of how to connect people of all ages to their natural environment. Birds were chosen as an example because of a personal curiosity for the animal, and because they are an accessible and tangible element of nature for all people, urban and rural. The first component is a Curriculum Development Guide created for the Wings Over Water program of the Montana Natural History Center. It synthesizes scientific research on Ospreys, relates central themes of the literature to Next Generation Science Standards (NGSS) and provides inventive activity ideas that could be implemented in middle school lesson plans. The second component is a self-guided tour box created for the PEAS Farm that includes information on various bird species I found on the farm during self-conducted bird surveys. The third component is a proposal for the University Center to install bird friendly technology to mitigate wildlife-human conflict and, through the ASUM Sustainability Center, to educate the campus community on the importance of that technology.

Ospreys in STEM: A Curriculum Development Guide

Prepared for:
Jénelle Dowling, Research Specialist and Program Coordinator for Wings Over Water

Prepared by:
Kat Olson, Environmental Studies M.S. 2019

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Introduction

Wings Over Water (WOW) is a program of the Montana Natural History Center that aims to make STEM research more accessible to teachers and middle school students. The program creates Osprey themed lesson plans consistent with Middle School (Grades 6-8) Next Generation Science Standards (NGSS), inspired by scientific literature on the raptor. All lessons are designed to be interactive and approachable to foster student interest in STEM fields. WOW then hosts a week-long teacher training each spring on how to implement their lesson plans and on how to effectively engage their students using a multidisciplinary approach. WOW's long-term goal is to address all Middle School NGSS using Osprey themed lesson plans.

This curriculum guide was created to supplement WOW's scope of work and is intended for internal use only. It includes a collection of annotated articles about the Osprey, found using the University of Montana's OneSearch. I searched for literature that included keywords such as "Osprey", "Pandion haliaetus", and "Accipitriformes" to narrow in on Osprey related articles. I then gathered and compiled a variety of Osprey articles that ranged from topics in pollution, migration patterns, population status, and more. The selection process was intentionally comprehensive to be able to associate various STEM themes from the literature to pertinent Middle School NGSS, which are listed after annotations. This association provided the basis for creating activity ideas that could be incorporated into future WOW lesson plans and are also listed after annotations for select articles.

By gathering and compiling scientific literature on Ospreys, I confront a broad question: how can STEM research be used to educate and excite future generations of learners? WOW approaches this by using lesson plans as a platform to relate ideas from scientific literature into real world activities for young students. This guide will provide WOW staff with necessary insight into the variety of Osprey literature available in the field and serve as a source of inspiration for future WOW lesson plans.

After this body of research is converted into lesson plans and taught to students, I am hopeful that students will nurture a greater appreciation for the natural environment and STEM fields in general. Instead of studying science in a book, students will be learning through experiences they will remember. This cognizance will instill positive attitudes toward STEM and the natural environment in young people, who will face the worst impacts of climate change and other great environmental issues of our time. By providing them with a hands-on environmental education, WOW will equip them with the knowledge necessary to confront those complex issues. Besides building a positive attitude toward science, my research will also be used to inform WOW staff of what research is currently being done, or has been done, on Ospreys. Increased understanding of these raptors, which are found on all continents except Antarctica, will increase understanding of our environment on a global and local level.

Contents by NGSS

Articles with Activity Ideas

No clear connection to Middle School NGSS

Connections to Middle School NGSS

MS-PS1-1: Develop models to describe the atomic composition of simple molecules and extended structures.

MS-LS1-5: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

MS-ESS1-2: Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

MS-ESS1-4: Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.

MS-ESS2-1: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

MS-ESS2-5: Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.

MS-ESS2-6: Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

MS-ESS3-2: Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

Contents

1. **Allen, L., Morrison, K., Scott, W., Shinn, S., Haltiner, A., & Doherty, M. (2018). Differences Between Stance and Foot Preference Evident in Osprey (*Pandion haliaetus*) Fish Holding During Movement. Brain and Behavior, 8(11), E01126.**
    - Lateralized and localized brain functions allow for complex actions to occur at the same time
    - Lateralization in birds is well studied during feeding and perching behaviors
        - Goshawks and Marsh Harriers show preferences for food holding with left leg
        - Parrots show preferences for food holding with left leg and perching with right leg
    - Lateralization during flight or foraging not well studied
        - Budgerigars show individualized preferences when presented with a left or right hole to fly through under a perceived threat
        - One study showed Ospreys tend to hold prey more often in right food when returning to the nest
    - Osprey ideal for studying lateralized preferences during flight because live fish are grabbed with talons rather than the beak
        - To stabilize the fish in air, one talon is typically positioned close to the cranial structures and one is typically positioned close to dorsal fin, meaning one foot must be in front of the other
    - Studied 5 data sets of Osprey pictures to assess lateralization preferences
    - Osprey showed no foot preferences for in-flight one-foot grabs or not-in-flight fish holding
    - During complex movements in flight-with-prey, showed preference for left foot forward stance
        - Authors unaware of other birds or animals that display stance preferences during movement or travel
        - Humans usually choose a left foot forward stance in board-in-motion sports, like skateboarding and surfing
    - Hypothesize that laterality of stance preference relates to complexity of Osprey movements
        - Controlling fish motion
        - Potential kleptoparasitism during flight – well documented by Bald Eagles
    - Due to sample size, results could be statistically insignificant

<u>**NGSS**</u>
No clear connection to Middle School NGSS.

2. **Bai, M., Schmidt, D., Gottschalk, E., & Mühlenberg, M. (2009). Distribution Pattern of an Expanding Osprey (*Pandion haliaetus*) Population in a Changing Environment. Journal of Ornithology, 150(1), 255-263.**
    - Studied nest site selection and distribution pattern at landscape level of German Osprey population
    - Demonstrated how to test predictions of Ideal Free Distribution (IFD) Theory on expanding population
    - Outlined IFD and its modified forms
        - IFD - Provides mechanistic explanations for the distribution of animals
            - H1 - Sites with higher basic quality are occupied earlier
            - H2 - When population size fluctuates, sites with higher basic quality are occupied more frequently

        - H3 - At any given time, density is higher at sites with higher basic quality
        - H4 - At any given time, fitness of individuals is equal across different sites
    - Ideal Despotic Distribution (IDD)
        - Predicts higher fitness at sites with higher basic quality (H4b) because dominant individuals prevent local density from becoming so high as to greatly depress their fitness
    - Ideal Preemptive Distribution (IPD)
        - Sites defined as definite areas of exclusive occupancy, thus the quality of a site is independent from local density
- Nest site selection
    - Preferred to nest in areas with more lakes and forests, less agricultural land and human settlement
        - supported higher densities and were occupied earlier
    - Water body most important factor in site selection. Importance of larger bodies over smaller ones
    - For nests on poles, sites with more forest occupied earlier with higher density
- Shifting distribution of expanding population
    - Later established nest sites located in areas with less forest and more agriculture - population as a whole expanded toward open landscape
- Breeding success and landscape pattern
    - Nests surrounded by more agricultural land have higher breeding success
        - Eutrophication in water near agriculture, possibility of higher resource availability
        - Potential predators live in forests, possibility of less predation pressure
    - Breeding success not reliant on distance to water bodies nor to substrate type (tree/pole)
- Distribution pattern
    - Did not support any of the hypotheses

Activity Ideas

Students can explore the role of nitrogen in the environment and the impacts it has on aquatic ecosystems. For example, students could learn the atomic composition of ammonium nitrate, a simple nitrogen fertilizer, and organic matter from animal waste. WOW curriculum can demonstrate how this flows through ecosystems by way of runoff and leaching, nitrification in sediments, and nitrous oxide contributing to climate change. The lesson could go further in explaining that runoff facilitates algae growth. Students could learn the equation for photosynthesis and its role in eutrophication of major water bodies. While this study suggests eutrophication may aid in resource availability for Ospreys, WOW could explore the long-term negative effects of eutrophication leading to anoxia of aquatic ecosystems, potentially eliminating important food sources for Ospreys.

NGSS

MS-PS1-1: Develop models to describe the atomic composition of simple molecules and extended structures.

MS-LS1-5: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
MS-LS1-6: Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.
MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
MS-LS2-3: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
MS-ESS2-1: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.
MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

3. **Bedrosian, B., Cain, S., Wolff, S., & Craighead, D. (2015). Migratory Pathways, Timing, And Home Ranges of Southern Greater Yellowstone Osprey. Journal of Raptor Research*, 49*(3), 325-332.**
    - Tracked migration movements of 9 Ospreys (5 juveniles, 4 adults) from 2 nests in Southern Greater Yellowstone Ecosystem of Northwestern Wyoming
    - Objectives
        - Define migration timing, routes, and over-wintering areas for this population
        - Report on family group dynamics of migration and home-range size of breeding and wintering areas
    - Osprey characteristics
        - All were bred or hatched in Grand Teton National Park (GTNP) in Northwest Wyoming
        - Primarily nested on natural substrates within GTNP, some nested on power line poles and artificial platforms
        - Cutthroat trout primary resident prey species
    - Followed 3 distinct migration routes, 2 not previously described
        - Migratory paths originated from northwest Wyoming
        - Migration corridors along both western and eastern sides of the Rocky Mountains and across Great Plains
        - Ospreys wintered in Texas Louisiana, and Northern Mexico
        - One adult male made major east-west migration before resuming normal north-south pattern
            - Returned along same path and repeated this migration pathway the following year
            - The magnitude of this east-west movement not previously documented
        - Did not exhibit stopover behavior in this study
    - Median nest initiation and fall departure dates were later compared to other studies
        - Likely due to high altitude of study area
        - Later spring runoff and melting, delaying prey availability
    - Wintering
        - Mainly wintered around Gulf of Mexico and Texas

        - One juvenile went as far as Guatemala
    - Tended to winter farther north than documented in other studies
        - Typical of leapfrog migratory pattern
    - Juveniles had longer wintering home ranges
        - Young Ospreys do not return to natal territories until 2nd year
    - Adults had strong fidelity to wintering areas and have tight home ranges
    - Breeding males wintered further south than breeding females
- Osprey density and productivity from Greater Yellowstone Ecosystem declining due to declining native prey populations
    - Likely due to local disturbance in Yellowstone Lake, although article does not provide specifics
    - Nest occupancy and productivity stable in Grand Teton National Park
- All 5 juveniles died/stopped transmitting before completing first migration cycle
    - Last locations near towns in Mexico and Central America
        - Suggests anthropogenic sources of mortality
    - Possible transmitter effects on young Ospreys
        - Other researchers noted similar potential issues
        - Could affect hunting capabilities or compromise fitness
- Overall, Ospreys studies differed in migratory timing, distance, and winter locations even though they were bred or fledged in the same geographical region

Activity Ideas

It would be interesting for students to be able to track local Osprey populations from the greater Yellowstone area through GPS. For example, Rob Bierregaard tracks east coast Ospreys and uses live interactive maps to show their migration progress throughout the year (http://www.ospreytrax.com/OspreyMainPage.html). Students could use migration routes to calculate how far an Osprey travels in a day, or a week, and calculate their average distance. Using different points, students can even calculate their average speed. Students can also track weather data and determine if that could have an influence on an Ospreys migration. From this data, teachers would be able to do an activity with their students to explain the phenomenon of weather. Rob also has individual maps and biographies on his website and students could choose to follow their favorite bird throughout the year. Through the Squam Lakes Nature Center in New Hampshire, students can even track birds on their smart phone (http://www.nhnature.org/programs/project_ospreytrack/osprey_maps.php). Other satellite tracking projects can be found here: http://www.osprey-watch.org/osprey/follow-osprey-migration-with-satellite-tracking-projects/

NGSS

MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-ESS2-5: Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.

MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

4. **Chen, Hale, Watts, La Guardia, Harvey, & Mojica. (2010). Species-specific Accumulation of Polybrominated Diphenyl Ether Flame Retardants in Birds of Prey from the Chesapeake Bay Region, USA. *Environmental Pollution,158*(5), 1883-1889.**
    - Important background
        - Chesapeake Bay supports one of the largest Osprey populations in the world
        - Brominated flame retardants largely present in textiles, thermoplastics, polyurethane foams, and electrical products
            - Most studied are polybrominated diphenyl ether (PBDE) flame retardant additives
                - Studies show that PBDEs have become widely distributed even on abiotic media and in remote locations
                - Studies show that PBDEs can induce changes in thyroid, vitamin A, glutathione homeostasis, oxidative stress, and courtship behaviors in American Kestrels
                - Osprey eggs collected in Washington and Oregon found concentrations of PBDE ~1000 ng/g wet wt. May reduce Osprey reproductive performance
    - This study aims to examine PBDE contamination in selected bird species and identify species specific contamination patterns
    - 13 Osprey eggs examined, in addition to 38 Peregrine Falcon, 12 Double Breasted Cormorant, and 10 Brown Pelican eggs
        - Tested for PBDE, PCBs, and DDE
    - Median PBDE concentrations in Ospreys were 290 ng/g wet wt
        - Similar to concentrations of DDE
        - One to two magnitudes lower than PCB
        - Comparable to other reports from Northern Bay
    - Pelicans and Cormorants had significantly lower PBDE levels and similar DDE concentrations compared to Ospreys
        - Could be because Osprey eggs were collected from more populated areas where PBDEs are common
        - Also, large tributaries are home to several sewage treatment plants (serve as potential contaminant source)
    - Biomagnification (BMF) for PBDEs in fish-Osprey egg food chain was 25.1, similar to PCBs (BMF=23.9) and DDE (BMF=18)
        - Study comparisons
            - Osprey eggs from Oregon had 12 - 13 BMF for PCBs, 103 - 112 BMF for DDE
            - Fish-marine mammal chains in Florida, 31 - 85 BMF for PBDE, 16 - 502 BMF for PCBs
            - Fish-marine mammal chains in North Sea, 11 - 53 BMF for PBDE
        - Though BMF potential of PBDE varies among food chains, a BMF >5 indicates substantial magnification

- Fish eating birds (Osprey, Cormorant, Pelican) and Peregrine Falcon had different PBDE congener distribution patterns
    - BDE-47 dominant congener in fish birds
    - May be subject to greater biomagnification
        - BDE-47 has been reported to be vulnerable to biotransformation in some terrestrial feeding birds of prey
    - BDE-153 dominant congener in Peregrine Falcon
        - Low biomagnification potential
        - Many higher brominated congeners only observed in Peregrine eggs
- BDE-209 (Deca-BDE) historically used in greatest amounts worldwide and only PBDE formulation still manufactured
    - Detected in all Peregrine eggs but no aquatic species
        - Species specific bioaccumulation
- Hazard Quotients (HQs) used to evaluate potential PBDE and DDE risks to Ospreys and Peregrines
    - HQs for DDE = 0.3 for Osprey and 1.7 for Peregrine Falcon
        - Moderate hazard to Peregrine via eggshell thinning
        - Observed 14% thinning in Ospreys and 11.4% thinning in Peregrine falcon in contrast with pre-DDT era figures
    - HQs for PBDE = 2.9 for Osprey and 1.0 for Peregrine Falcon
        - Moderate hazard to both species through reproductive performance impairment
        - Greater threat to Osprey than Peregrine Falcon

Activity Ideas

Students could watch a video on DDT and its impacts on bird populations, or they could even read the first chapter (or other select sections) of *Silent Spring* as a great introduction to human impact on their surrounding environment. There would be an opportunity to explore the concept of bioaccumulation from human created chemicals. Students can learn the specific sources of chemicals like DDT and how it permeates throughout ecosystems. To keep information current, it can be explained that there are threats like PBDEs and PCBs that work the same way as DDT through bioaccumulation and negatively affect the same birds we fought to protect in the DDT era.

NGSS

MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

5. **Cushing, R., & Washburn, B. (2014). Exploring the Role of Ospreys in Education. Journal of Raptor Research, 48(4), 414-421.**
    - Experiences in nature are important in shaping early environmental consciousness and ultimately the expression of pro-environmental attitudes and behaviors during adulthood
    - Experience based learning opportunities in natural settings can be effective in producing positive environmental attitudes and behaviors in students

- Because Osprey have highly visible nest sites and ability to live near humans, there is abundant opportunity for observation and learning
- Osprey as ecological model within primary education curriculums (provides several tables with list of resources)
    - "Ospreys are Special" 3rd grade curriculum
    - Conanicut Island Raptor Project
    - "The Return of the Fish Hawk"
    - Rutland Water Osprey Project
- Potential roles and opportunities for Ospreys in education
    - Educational resources
    - Technology in secondary and postsecondary education
    - Making international connections
    - Integration of research and education
    - Citizen science - crowd sourcing data
- This paper provides excellent tables and descriptions of successful Osprey education programs, Osprey books and literature, and a list of webcams all over the world. It can be used as a comprehensive reference during the creation of lesson plans.

Activity Idea

There are many free educational materials, ranging K-12, that WOW can access after making a free account through Rutland Ospreys (http://www.ospreys.org.uk/free-school-resources/). For World Osprey Week, individual schools can sign up on their website to connect to other schools along Osprey's migration flyway. Students can connect from faraway places to share projects and their Osprey stories (http://www.ospreys.org.uk/osprey-flyways-project/). Perhaps this idea could be implemented in the U.S. using migrating Ospreys here.

6. **DeCandido, R., Bierregaard, R. O., Martell, M. S., & Bildstein, K. L. (2006). Evidence of Nocturnal Migration by Osprey (*Pandion haliaetus*) in North America and Western Europe. *Journal of Raptor Research, 40*(2), 156-158. doi:EONMBO]2.0.CO;2**
    - Reviews observations of Ospreys migrating at night over land and sea
    - Based on observations, no tendency by Ospreys to start overwater trips early in the day to reduce nighttime flight
    - Evidence increasing of Ospreys and other raptors migrating at night with use of satellites

NGSS

MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

7. **Edwards, T. (1989). Similarity in the Development of Foraging Mechanics Among Sibling Ospreys. *Condor, 91*(1), 30-36.**
    - Investigates effects of interacting juveniles on the development of each other's behavior
    - Examines whether individual young show differences in foraging behavior or whether certain foraging techniques are so important that all young eventually show same behavior
    - Examines whether foraging behaviors develop at similar rates among young Ospreys
    - Behavioral data for 8 young Ospreys in 1985 and 14 young in 1986 were analyzed

- Fledglings earliest successful capture was 11 days after fledging
    - All made at least 1 successful capture 20 days post fledging
- Average capture success increased with age
- Difference in capture success of singleton and related young was most pronounced from 90-120 days post fledging
- At the end of post fledging, success rates did not significantly differ
- Capture success of related young were higher than those of singleton young in both areas
    - Siblings did not differ from one another regarding average capture success
- Singleton young exhibited greater variation among one another regarding average capture success
- Some singleton young had significantly lower success rates than related young and some singleton had similar success rates to related young

NGSS

MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
MS-LS2-3: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

8. **Elliott, John E, Levac, Joshua, Guigueno, Mélanie F, Shaw, D Patrick, Wayland, Mark, Morrissey, Christy A, Muir, Derek C. G., Elliott, Kyle H. (2012). Factors Influencing Legacy Pollutant Accumulation in Alpine Osprey: Biology, Topography, or Melting Glaciers? Environmental Science & Technology, 46(17), 9681-9689.**
    - Persistent organic pollutants (POPs) have accumulated in snow crystals of arctic and alpine environments
        - Contaminants are released at a higher rate into receiving waters from glacial melting caused by climate change
    - Examined topographical and ecological influences on contaminants in Osprey from 1999 to 2003 in western Canada using egg and plasma samples
        - Hypothesized that contamination would be greater for birds feeding at higher trophic levels and in drainage basins at increased elevation and with more coverage in permanent snow and ice
    - At higher elevation lakes, the summer was too short for successful breeding. Efforts were refocused to lower altitude lakes and catchments with substantial alpine and glaciated terrain
    - Fish type available and taken by Ospreys varied widely, from benthic cyprinids to pelagic feeding salmon,
        - Due in part to anthropogenic modification of the food systems (impoundments and introduction of non-native game fish)
    - Lower levels of contamination in small lakes draining areas of large watersheds, contrary to predictions that lakes would be contaminant sinks for large watersheds
        - HCB, chlordane, and mean PCBs decreased with watershed size
        - Toxaphene, mean DDT, and HCB decreased with watershed size divided by lake size
    - Decrease in the proportion of lower chlorinated PCBs, HCB, and DDT with elevation and glacial area

- Mean DDT decreased significantly in Osprey tissues with elevation and portion of glacial cover within watershed, in part due to local contaminant inputs at lower elevations
- Toxaphene, never used as an insecticide in western Canada, was found at greater concentrations in Osprey samples at higher elevation drainages with more permanent snow and ice cover, indicative of atmospheric loadings
- Found lower POPs in higher elevation and more glaciated drainages, inconsistent with hypothesis
    - Could be due to long term temporal trends in glacial extent – 10 year delay in maximum flow to high elevation mass relative to depositional trends

<u>NGSS</u>
MS-LS1-5: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-ESS2-1: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.
MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

9. **Ewins, P. (1997). Osprey (*Pandion haliaetus*) Populations in Forested Areas of North America: Changes, their Causes and Management Recommendations. Journal of Raptor Research, *31*(2), 138-150.**
    - Begins reviewing history of osprey populations greater than 100 years ago and since the 1930s with a focus on DDT
    - Speculates that prime nesting trees are very scarce in many former breeding areas due to massive reductions in forest
    - Reviews ideal nest site factors. Suspects that, historically, Ospreys nested further away from water because there were more nesting site options. Humans generally do not cut down trees close to waterways as to provide a back drop for recreationalists, which is why we see Ospreys frequently nesting near water
    - Artificial nest sites are not a viable long-term alternative.
    - Reviews current forest management guidelines for Ospreys, including buffer zones, foraging habitat restrictions, and general guidelines. Management varies widely across North America and needs new review. Most management plans written when Ospreys were more threatened. Stresses for decision making in an ecosystem context.

<u>NGSS</u>
MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.
MSETS1-1: Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions

10. **Farmer, C., Safi, K., Barber, D., Newton, I., Martell, M., & Bildstein, K. (2010). Efficacy of Migration Counts for Monitoring Continental Populations of Raptors: An Example Using the Osprey (Pandion haliaetus). The Auk, 127(4), 863-870.**
    - Large, sparse, or inconspicuous bird species are difficult to reliably count during mass-engagement or multi-site counting schemes, like the Breeding Bird Survey
    - Counts at a small number of sites with fewer observers can capture large-scale population trends
    - Used satellite tracking data for Ospreys migrating in North America to investigate the geography of migration and its relationship to the distribution of migration watch-sites. Objectives:
        - Estimate probability of passing within detection range of at least one watch-site
        - Determine whether Ospreys migrated along a broad front or were concentrated in a way that makes migration monitoring an effective means of estimating population trends
        - Identify important migration watch-sites for sampling Ospreys from three sectors of their northern breeding range (eastern, midwestern, northwestern)
    - 36% of paths in eastern North American intersected active watch-sites, 11% midwest, 10% NW
        - Eastern North America believed to support the majority of autumn passage population
    - 23% of migrants were potentially detectable at one or more watch-sites continent wide
        - 33% eastern North America, 6% Midwest, 5% NW
    - Results show that Ospreys migrate along several narrow fronts, contrary to the characterization of Ospreys being a broad-front migrant
        - Concentration along the coast of Gulf of Mexico in autumn suggests that Ospreys are dependent on land bridges and will follow them when available
            - Also apparent in European and African migrations
            - Ospreys will detour around large bodies of water, despite being able to cross them
    - Conclusions
        - Migration counts are an effective means of monitoring North American Osprey populations
        - There is a need to expand monitoring efforts outside the eastern US

Activity Idea

Take students on a breeding bird survey or a raptor count at MPG Ranch or Rogers Pass.

NGSS

MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

11. **Fowler, D., Freedman, E., Scannella, J., Kambic, R., & Farke, A. (2011). The Predatory Ecology of *Deinonychus* and the Origin of Flapping in Birds (The Predatory Ecology of *Deinonychus*). PLoS ONE, 6(12), E28964.**
    - Recently published sibling study showed for the first time that Accipitridae possess hypertrophied talon (D-II claw) used for prey immobilization
        - Similar to cretaceous carnivorous dinosaur *Deinonychus antirrophus*
    - This paper aims to elucidate functional morphology of the deinonychosaurian foot by comparison to findings of sibling study (Raptor Prey Restraint model - RPR)
    - RPR model explains
        - Grasping foot of Deinonychosauria is interpreted as an adaptation for holding on to prey as the predator's body weight pins down its victim
        - Positioning/balance maintained by anchoring D-II claw into prey (also preventing escape) and assisted by "stability flapping" and movement of beam like tail
        - Deinonychosauria probably similar to accipitrids in eating prey alive because they lack any specializations for prey dispatch
    - D-II claws and pinning behavior
        - Large size and high curvature of D-II claw suggests it is used for pinning down prey, same function as extant Accipitridae
        - Best positioned for max leverage
        - Fowler et al. points out that in non-carnivorous extant birds, D-III claw is the largest and less curved
    - Grasping feet
        - Deinonychosauria and extant accipitridae have elongated phalanges and D-II is hyperextensible
        - Grasping adaptations of the digits not as extremely developed as extant raptors
    - Eating, jaws, and teeth
        - Using RPR model, explains that jaws are used for dismemberment of prey, not attack or restraint of larger prey
        - Weak bite force in Deinonychosauria and extant raptors
        - Deinonychosaurs have hooked posterior denticles. Enhance effectiveness of the jaws' grip on the prey
    - Using RPR model, Fowler et al. thinks it unlikely that Deinonychus pack hunted, as previous studies suggest. Because of anatomy, they mostly preyed on animals smaller than themselves
    - Using RPR model, Fowler et al. suggests grasping foot first evolved for predatory purposes, not to grip branches for perching as previous studies suggest
    - "Stability flapping" hypothesis
        - Stability flapping could have been used during predatory activity
        - Supports "flapping first" model
            - flapping and associated aerial capability can be evolved independently of a flight function
        - Stability flapping less demanding than flight and represents intermediate aerial ability

<u>Activity Ideas</u>

WOW could create a lesson plan exploring the similarities and differences of Deinonychosauria and extant accipitridae, such as the Osprey, to show the evolution of dinosaurs into modern birds. The lesson could begin with an overview of how sedimentary layers relate to geologic time periods and how fossils are dated using that information. The anatomical similarities between the two species should be identified and theory of evolution explained. The relationship between stability flapping and flying as it pertains to adaptation by natural selection could also be identified. As a fun experiment, students could "hold" an object with their feet, testing if their balance is better with their arms down at their sides or with their arms straight out, moving or flapping.

Deinonychosauria fossils are coincidentally found in the Kootenai Formation of western Montana. Perhaps there is an opportunity for collaboration with local geologists, paleontologists, and other scientists to take a field trip to study sites around this area.

NGSS
MS-LS4-1: Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.
MS-LS4-2: Apply scientific ideas to construct an explanation for the anatomical similarities and differences among modern organisms and between modern and fossil organisms to infer evolutionary relationships.
MS-LS4-6: Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.
MS-ESS1-4: Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.

12. **Gallagher, A., Lawrence, M., Jain-Schlaepfer, S., Wilson, A., & Cooke, S. (2016). Avian Predators Transmit Fear Along the Air–Water Interface Influencing Prey and their Parental Care. *Canadian Journal of Zoology,94*(12), 863-870.**
    - Predators can transmit fear of being killed throughout ecosystem
    - "Fear effects" can significantly alter behavior, energetics, and life histories of prey species
        - May be more important than direct mortalities in shaping food web patterns
    - Hypothesis: The presence of aerial predators can significantly alter fish parental behavior
        - Study uses realistic model of Osprey on nesting pumpkinseed (common prey for Osprey) to test
    - Each experimental series began with aggression test and then a 12-minute recording period consisting of 3 phases
        - Phase 1: pre-stimulus, 5 minutes
        - Phase 2: stimulus (presence/absence of predator model), 2 minutes
        - Phase 3: post stimulus, 5 minutes
    - It took 8 seconds on average for fish to respond to Osprey model
    - Predator exposed fish had higher number of trips outside the nest, burst behavior events, and dorsal spine erections during phase 2, relative to control fish
    - In-nest rotations and nest maintenance behavior significantly affected
        - Overall, exhibited 5 times lower maintenance than control
        - Exhibited approximately 10 fewer rotations after predator cues
        - Exhibited approximately 5 lower nest maintenance behaviors

- Predator presence effects
    - Dorsal spine erection was 126% higher compared to control
    - Spent 60 times more time outside the nest
    - Burst swimming behavior exhibited 4 times more
- Demonstrates "fear" of predators operates in 3 dimensions and across media
- Avian risk effects can cause prey to alter key parental behaviors
    - Pumpkinseed engaged in vigilance displays and avoidance behaviors that were prioritized over parental behaviors) nest guarding and egg maintenance)
    - Threat of predation has direct effects on prey and their offspring
- Study only looked at real-time effects and cannot determine chronic impacts on fish fitness

NGSS

No clear connection to NGSS.

13. Green, D., & Ydenberg, R. (1994). Energetic Expenditure of Male Ospreys Provisioning Natural and Manipulated Broods. Ardea,82(2), 249-262.

- Male Ospreys capture the majority of prey eaten by female and chicks prior to fledging and spend between 65-85% of their day perched at or near nest
    - Suggests that time constraints are unimportant for Ospreys
- Study evaluates whether energetic constraints limit the capacity of the male Ospreys to provision nestlings or provide post fledgling care
    - Daily energetic expenditure (DEE) of male Ospreys is estimated
    - Factors affecting DEE are investigated to determine whether physiological constraints limit energetic expenditure at any point in breeding season
    - Examines consequences of variation in brood size for parents and young
- Male Ospreys provisioning nestlings spent only 1.34 hr/day flight-hunting and were inactive for 13 of the 16 hours of daylight
    - The longest a male was observed to flight hunt was 4.7 hours (31% of the active day)
    - Time constraints to foraging appear unlikely to limit brood size
- Digestive tract's capacity to assimilate nutrients or energy from food does not appear to limit brood size
    - Mean DEE of male Ospreys was 1248 kJ/day. Sustainable energy expenditure for a male Osprey weighing 1428 grams is predicted to be 1913 kJ/day
    - DEE only came within 20% of the maximum they are predicted to be able to sustain (on 8 of the 82 days of observation)
- DEE appeared to be dependent on number of chicks in their brood
    - Although males provisioning large broods expended more energy, their intake rates were no different than males with smaller broods
        - Consequently, they probably lost more body mass during breeding season
- Despite relationship between natural brood size and male DEE, brood size does not have a direct result on DEE
    - Male Ospreys neither increased their energetic expenditure nor reduced their food intake when provisioning experimentally enlarged broods
        - Consequently, chick intake rates reduced and they gained wait at a slower rate
        - Could reduce post-fledgling survival

    - The failure of males to respond to manipulation of brood size could be interpreted as an "unwillingness" to pay the costs associated with increased energetic expenditure
- Although not statistically significant in this study, results support the conclusion that females alter their behavior and incur energetic cost when provisioning enlarged broods

NGSS

MS-LS2-3: Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.

14. Henny, C., Kaiser, J., Grove, J., Johnson, L., & Letcher, R. (2009). Polybrominated Diphenyl Ether Flame Retardants in Eggs May Reduce Reproductive Success of Ospreys in Oregon and Washington, USA. Ecotoxicology, 18(7), 802-813.

- Objectives:
    - To determine PBDE and total-α-HBCD concentrations in Osprey eggs at 9 locations in OR and WA between 2002 and 2007 and compare congener profiles among locations
    - Compare temporal trends and evaluate spatial patterns in PBDE concentrations in Osprey eggs
    - Evaluate reproductive success at each nest to determine if an association exists with PBDE residue concentrations.
    - Determine if eggshell thickness is related to PBDE concentrations
    - Compare PBDE concentrations between Osprey and Double-Crested Cormorants in locations where both species nest
- All eggs collected for study had quantifiable PBDE concentrations
    - Willamette River eggs contained highest mean concentrations and highest individual congener concentrations
- Temporal trends evaluated for 22 eggs collected from Seattle area
    - PBDE concentrations did not increase significantly
    - Two congeners (BDE28 and BDE100) increased over time
- 10 nests from the Willamette River in 2006 and 20 nests from the Columbia River in 2007 showed a negative relationship between productivity and mean PBDE
- All eggs were previously evaluated for organochlorine pesticides, PCBs, dioxins, furans and mercury
    - Only 4 eggs from the Yakima River had contaminants at concentrations that adversely impact Osprey productivity
- No indication from dataset that eggshell thickness was related to PBDE concentrations
- Mean PBDEs and congeners BDE28 and BDE47 were significantly higher in Osprey eggs than the Double-Crested Cormorant, possible due to the Osprey catching larger fish

NGSS

MS-LS1-5: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.

MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

15. **Horton, T., Bierregaard, R., Zawar-Reza, P., Holdaway, R., & Sagar, P. (2014). Juvenile Osprey Navigation During Trans-Oceanic Migration. PLoS ONE, 9(12), PLoS ONE, Dec 10, 2014, Vol.9(12).**
    - Attempts to answer: How do Ospreys have the ability to compensate for wind drift during open ocean migration?
    - Hypothesis: Juvenile Ospreys fully compensate for drift during long distance migration over open ocean
    - Analyze geospatial, meteorological, and magnetic coordinate data derived from GPS track data for ten Ospreys <1 year old migrating across Atlantic Ocean
    - Trans-Oceanic movements of Ospreys
        - 9/10 Ospreys arrived on Caribbean islands after 36-54 hours of non-stop flight proving that juveniles are capable of continuous day and night migration
        - Mean distance of 2162 km (1343 miles) over 52 hours, averaging travel velocity of 41.3 km/h (~25mph)
        - 23/25 track segments exhibited straightness index values >0.98. Every bird had navigational capacity to be no more than 10km off course for every 1000km travelled
    - Wind Analysis
        - Range: 2-70 km/h (1-43 mph), Mean: 27 km/hr (17 mph), mean direction was NE
        - Support hypothesis because results demonstrate juveniles overcompensate for perpendicular wind drift >51% of the time
        - Positive covariation between forward movement velocity and tailwind velocity
            - Forward movement velocity is higher with stronger tailwinds
        - Negative covariation between active forward movement velocity and tailwind velocity
            - Stronger tailwinds mean lower active forward movement velocities
            - Birds experiencing headwinds maintained highest active forward movement velocities (often >50 km/h)
    - Mechanisms of positional orientation
        - Possible orientation by magnetic or gravitational cues
        - Analysis reveals that Ospreys would not have been able to compensate for their displacement by wind if using bicoordinate geomagnetic F-I space to navigate
        - Regression coefficients for any of the 300 paired track segments were insignificant
    - Argues that for animals showing orientational responses to magnetic cues, magnetic cues are more likely to be defined relative to a location that is meaningful to the animal such as the location of home
        - Transformed data to change perspective from which coordinate space is viewed
        - Most of the track segments follow the transformed magnetic trajectories
    - Chord and clock navigation
        - Chord
            - Scalar distance or gradient between two locations
        - Clock
            - Natural mechanism for gauging the passage of time
        - Provides a means of solving an animal's core ecological need of arriving in a biologically suitable habitat at a biologically suitable time
        - 2 observations

- Naïve Ospreys are capable of maintaining remarkably precise constant course movements means they have a profound ability to locate themselves in at least one coordinate space.
- Naïve Ospreys are compensating for headwinds demonstrates their movements are paced through some means of keeping time

<u>Activity Ideas</u>

Many scientific hypotheses suggest that birds use magnetic and gravitational fields to navigate, a concept that can be explored using Ospreys. Students can begin the lesson zoomed out, learning about the role of gravity within galaxies and our own solar system; how our solar system is part of the Milky Way Galaxy, one of many galaxies in the universe, and that gravity once played a role in creating our solar system and continues to play a role in how the objects in our solar system interact. Students can create their own representation of our solar system through some type of interactive modeling. It can be explained that each planet, including Earth, has its own gravitational field and its own magnetic field, and students can learn how these fields work, such as how Earth's core materials create its magnetic field. Students can play with magnets in class to explore this concept. The activity's scope can be narrowed to show that these fields impact how life has evolved to interact with Earth. For example, this study suggests Ospreys use Earth's magnetic field to navigate and, as briefly summarized below, another study (see below) suggest that pigeons use Earth's gravitational field to navigate. Students can learn how to use a compass to explore navigation by the magnetic field, which is a great life skill to have!

Using this study, students can also learn about climate and the Earth processes that cause climate patterns, specifically as it relates to global air circulation. Climate is a complicated process, which is why weather can only be predicted days in advance and with limited certainty. Cause and effect relationships that create weather patterns can be explored, such as the movement of air masses creating wind. Students would be able to relate this to Osprey's navigational capabilities over open ocean migration. Teachers can point out how Ospreys migrate to different climatic regions depending on the time of year and how Ospreys adjust for weather, such as wind conditions, along their migration route.

<u>Pigeon Study</u>

Blaser, N., Guskov, S., Entin, V., Wolfer, D., Kanevskyi, V., & Lipp, H. (2014). Gravity anomalies without geomagnetic disturbances interfere with pigeon homing--a GPS tracking study. *The Journal of Experimental Biology, 217*(Pt 22), 4057-67.

- Conducted series of studies in Ukraine between 2009 and 2012 to analyze the orientation behavior of pigeons in relation to gravity anomalies
    - Released homing pigeons from within a circular gravity anomaly showing normal magnetic values
    - Predictions
        - The vanishing bearings of pigeons released in the center of the gravity anomaly should not be different from those of the control pigeons
        - Pigeons crossing the border zone of the gravity anomaly should show changes in their flight direction compared to control birds
- Data confirmed predictions and supported the hypothesis of gravitational navigation for pigeons

NGSS

MS-ESS1-2: Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.
MS-ESS2-5: Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions.
MS-ESS2-6: Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.
MS-PS2-3: Ask questions about data to determine the factors that affect the strength of magnetic and electric forces.
MS-PS2-4: Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

16. **Junda, J., Greene, E., & Bird, D. (2015). Proper Flight Technique for Using a Small Rotary-Winged Drone Aircraft to Safely, Quickly, and Accurately Survey Raptor Nests. Journal of Unmanned Vehicle Systems, 3(4), 222.**
    - Typically, 2 standard methods for surveying raptor nests
        - Ground based
        - Conventional manned aircraft
    - Developed technique for using UAV
        - Quicker and more accurate
        - Mitigates aggressive defense behavior
        - Successful in 95% of surveys
        - 2 essential participants
            - Pilot - responsible for flying aircraft
            - Spotter - monitors and keeps pilot informed about adult behavior
    - Pre-flight survey to meet standard conditions
    - Pre-approach
        - Pilot - prepares UAV
        - Spotter - identifies distance to nest and individual adults
    - Approach stage
        - Begins when pilot/spotter approach nest on foot
        - Spotter - vocalized behavior
    - Pre-flight setup
        - Begins within 20m of nest
        - Pilot - identifies appropriate launch/landing site, launches with camera focused down
        - Spotter - vocalized behavior
    - Survey stage (flight)
        - “Hover and wait” for pictures
    - Withdraw
        - Clean up and simultaneously withdraw
        - Continue to call out bird behavior
    - Reviews costs/benefits regarding different UAVs

<u>NGSS</u>

MS-ESS3-3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
MS-ETS-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

17. **Junda, J., Greene, E., Zazelenchuk, D., & Bird, D. (2016). Nest Defense Behaviour of Four Raptor Species (Osprey, Bald Eagle, Ferruginous Hawk, and Red-Tailed Hawk) to a Novel Aerial Intruder--a Small Rotary-Winged Drone. Journal of Unmanned Vehicle Systems, 4(4), 1-11.**
    - Compare defensive behavior of 4 raptor species when exposed to an unmanned aerial vehicle (UAV): Osprey, Bald Eagle, Ferruginous Hawk, and Red-Tailed Hawk
    - Examined responses of Osprey within a single nesting cycle
    - All showed active nest defense response but a range of behavior observed
    - Ospreys
        - No more aggressive to UAV than they were to humans
        - Only species to strike the UAV
        - Showed most aggressive nest defense response during "approach" stage
        - Showed highest defense index during "at nest" stage
    - Bald eagles
        - Showed the lowest response for all stages
        - Showed increased response to UAV
    - Ferruginous hawks
        - Variable range of response
        - Did not observe a return to the nest
    - Red tailed hawks
        - Call rate doubled during "at nest" stage

<u>NGSS</u>

MS-ESS3-3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
MS-ETS-2: Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.
MS-ETS1-4: Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

18. **Kinsella, J., Cole, R., Forrester, D., & Roderick, C. (1996). Helminth Parasites of the Osprey, *Pandion Heliaetus*, in North America. *Journal of the Helminthological Society of Washington, 63*(2), 262-265.**
    - Examined 17 dead Ospreys for parasites, 28 species of helminths found in various regions of the body
    - 7 species are specialists to Ospreys only – large compared to other raptors. Possibly because of reproductive and ecological isolation from other raptors since the Pleistocene

- Highly probable that those 7 species were acquired through fish as an intermediate host
- The generalist species found could potentially act as biological tags reflecting the migratory behavior of the host, however study is not precise enough to warrant such a conclusion
- Results of the study are nicely portrayed in two tables

NGSS

No clear connection to NGSS

19. **Langner, H., Greene, E., Domenech, R., & Staats, M. (2012). Mercury and Other Mining-Related Contaminants in Ospreys Along the Upper Clark Fork River, Montana, USA. *Archives of Environmental Contamination and Toxicology, 62*(4), 681-695. doi:10.1007/s00244-011-9732-5**
    - Tested blood and feather samples along Upper Clark Fork River Basin for Hg and USEPA priority contaminants (As, Cd, Cu, Pb, and Zn)
    - Tested sediment samples for same elements. Should reflect local environmental conditions and provide baseline data to assess contaminants in Ospreys after remediation/restoration
    - Highest concentrations in sediments measured between Warm Springs and Drummond, then further decreased downstream
    - Blood and feather samples reflect level of sediment contamination for some elements but not others
    - Highest concentrations of Cu, Pb, and Zn in blood samples in 2008 because of high spring runoff and breach of Milltown Dam. This suggests high suspended contaminant loads positively corresponds to high contamination of fish
    - Hg concentrations seem to be a function of geographic location of nests
        - Hg lower upstream, consistent with previous observations for mountain river systems
        - Hg concentrations increased several-fold in sediment downstream from Flint Creek, which has extensive historic gold and silver mining and smelting operations

Activity Ideas

The same concepts I outlined in number 3 above, such as bioaccumulation, could be addressed here. This study can be used to provide a local context for students and perhaps they can take a field trip to Milltown Dam or a different superfund site to witness human impact to the environment. Students can learn about mercury health effects in Ospreys and in humans. They should understand that because of the demand from an increasing population, mining and associated toxic by-products are widespread all over the world. Students can research different islander populations that also rely on fish as their main source of sustenance, identifying their body burdens from mercury poisoning. How does this compare to levels in the Osprey? How does it compare to inland populations that don't eat as much fish? This could be related to the concept of environmental justice, similar to the lesson plan on page 38.

NGSS

MS-LS1-5: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

20. **Lazarus, R., Rattner, B., Brooks, B., Du, B., McGowan, P., Blazer, V., & Ottinger, M. (2015). Exposure and Food Web Transfer of Pharmaceuticals in Ospreys (Pandion Haliaetus): Predictive Model and Empirical Data. *Integrated Environmental Assessment and Management, 11*(1), 118-129**
    - Pharmaceuticals primarily enter the environment through waste-water from bulk drug production, sewage plants, septic systems, and biosolids from agricultural lands
    - Study examined the bioaccumulation of pharmaceuticals and their fate in the water-fish-Osprey food web
        - Describes framework and findings of screening-level exposure assessment to estimate daily and cumulative 10-day intake of pharmaceuticals
        - Analyzed 23 compounds and an artificial sweetener in water, blood plasma of fish, and Osprey nestlings from waterways in the Chesapeake Bay
    - Screening-level assessment identified a subset of 15 of 114 compounds that warrant further investigation (based on potential to exceed Human Therapeutic Dose [HTD])
        - 6 of the 15 compounds could evoke pharmaceutical responses and possible toxicity in invertebrates and fish based on their bioconcentration factor
        - HTDs for 3 xenobiotics (foreign substances to human body or ecosystem) were exceeded in adult Ospreys at calculated theoretical half-lives, which were less than human half-lives
            - Ospreys could accumulate HTD within 3-7 days of exposure in a low-flow scenario
    - 18 pharmaceuticals and an artificial sweetener were detected in water samples
        - Concentrations and frequencies of detection greatest on Black River which receives 180 million gallons/day from a wastewater treatment plant
    - In fish, frequency, concentrations, and hazard quotients were low and far less critical than environmental concentrations
    - Diltiazem, an antihypertensive drug, was the only analyte detected in water, fish, and biota
        - Aquatic risks of diltiazem remain poorly understood
    - Only 3 of 24 analytes quantified in Osprey plasma exceed HTD
        - Diltiazem had greatest potential to bioaccumulate
        - No adverse impacts observed

NGSS

MS-LS1-5: Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.
MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

21. **Lohmus, A. (2001). Habitat Selection in a Recovering Osprey *Pandion haliaetus* Population. Ibis, 143(4), 651-657.**
    - Author tests sequential habitat occupation theory in Estonian Osprey populations
        - Identify factors that influence the locations of nests
        - Examine whether foraging conditions are correlated with the initial year of nest site occupancy and with their productivity
    - The average productivity of Ospreys decreased as numbers rose, a pattern of reoccupation
        - Newcomers had lowered productivity compared with settled pairs
        - Sites closer to foraging grounds with more lakes around were occupied first and had the highest productivity
    - Nest location
        - Ospreys preferred larger lakes to smaller ones
        - On average, nests were situated 5km from foraging grounds

<u>**NGSS**</u>

MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

22. **Martell, M., Englund, J., & Tordoff, H. (2002). An Urban Osprey Population Established by Translocation. Journal of Raptor Research, 36(2), 91-96.**
    - Translocation has become a widely used conservation management tool for many species of wildlife
    - Released 143 translocated Osprey nestlings at 8 sites in the Twin Cities area from 1984 – 1985
    - Examine characteristics of new urban population established by translocation
        - Productivity and nesting
            - Productivity measured above the 0.9-1.3 young/occupied nest necessary for population stability
            - Used artificial nest platforms, increased nesting success
            - Early dependence on a small number of highly productive individuals and sites is expected
        - Site characteristics
            - Most productive sites were among the oldest and had little or no turn-over of males
        - Returns
            - Released birds more likely to return to the study area than wild-fledged Ospreys
            - Released birds responsible for more nesting attempts than banded wild-fledged birds
            - Females dispersed significantly farther than males (mean distance of 384km vs 27km)
                - Could be related to the amount of effort each sex depends on territory competition vs raising young
        - Migrations
            - Translocated Ospreys use similar migration patterns and routes as other Ospreys in the region

NGSS

MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.
MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

23. **Martell, Mark S., Bierregaard Richard O., Washburn Brian E., Elliott John E., Henny Charles J., Kennedy Robert S., & MacLeod Iain. (2014). Spring Migration of Adult North American Ospreys. *Journal of Raptor Research, 48*(4), 309-324.**
    - Investigates spring migrations of Ospreys
        - Determine timing, duration, and migration routes of spring migrations
        - Determine if differences in migration patterns exist between sexes and among 3 breeding populations
        - Compare consecutive fall and spring migrations of individuals
    - Migration routes
        - In all 3 populations, individual Ospreys followed same route each spring and fall
            - Individuals that were tracked for more than 1 year followed same route each spring
        - East Coast Ospreys
            - Funneled by geography in fall migration
                - Most wintered in South America (a handful wintered in Florida and Caribbean Islands)
                - Fall migration broadened from 460km at 39°N to 800km toward Florida
                - Narrowed to 20km near East Cuba
                - Expanded to 960km at 13°N near South America
            - Funneled by geography in spring migration
                - Involved nocturnal migration
                - Left northern coast of South America and made landfall in Haiti, Jamaica, or Cuba after 27 to 40 hours (between 680 and 1200 km)
                - Once across Caribbean Sea, nearly all followed spine of Cuba, crossed to Florida Keys, then proceeded North toward wintering grounds
            - Spring migration front narrower than fall
                - At 17°N and 39°N, spring front half as wide as in fall
                - 24°N to 33.5°N, front less than 200km wide
                - Median longitudes at checkpoints no more than 75km apart
        - Midwest Ospreys
            - Noted poor data and limited accuracy because of small sample size

        - Population splits into 2 fronts
            - Birds heading toward Caribbean passed 30°N at 950km wide
            - Birds using Central American route to South America cross 30°N at 950km wide
            - Returned via same flyway they took heading south
    - Western Ospreys
        - Considered "broad front" migrants
        - At 44°N in fall, front was 800km wide and spread to 1640km wide by 30°N
            - Width of spring migration at these points is near identical
- Spring migration departure dates
    - Male and female departure dates not significantly different
    - Median departure date from wintering grounds for East Coast Ospreys earlier than Western Ospreys, median departure date for Midwest Ospreys was intermediate
    - Overall, Ospreys departed as early as February 9 and as late as April 19
- Days spent on spring migration
    - East coast Ospreys
        - Females spent more days on spring migration than males
    - Midwest Ospreys
        - Male and females spent similar number of days
    - Western Ospreys
        - Males spent twice as many days on spring migrations than females
- Distance travelled on spring migrations
    - Total distance ranged from 1918 to 8071km, averaging 4666km
    - No differences in average daily distance traveled between sexes or breeding regions
    - Overall, average daily distance traveled by individuals ranged from 74 to 458km per day, averaging 237 per day
- Breeding area arrival dates
    - Median arrival dates of females same as for males
    - Median arrival dates onto breeding grounds for East Coast Ospreys earlier than for Midwest and Western Ospreys
    - Overall, ranged from March 11 to May 15 with average of April 8
    - For birds tracked for more than 1 year, arrival date varied from 0 to 16 days
- Comparison of fall and spring migration of individuals
    - Compared 34 birds over a total of 51 migration cycles
    - Male Ospreys
        - Spent twice as many days migrating in fall than spring
        - Traveled farther each day during fall than spring
    - Female Ospreys
        - Spent similar amount of days during fall and spring migration
        - Distance traveled each day is similar during fall and spring
    - Geographic location of breeding areas influenced migration characteristics
        - East coast Ospreys spent fewer days on spring migration and traveled shorter distance during spring migration than fall
        - Western Ospreys had similar migration characteristics in fall and spring

        - Sample size for Midwest Ospreys too small for statistical comparison
- Stopovers during migration
    - Male Ospreys spent 4 times as many of their travel days on stopovers during fall migration compared to spring
    - Females Ospreys spent a similar amount of time during stopovers in fall and spring
    - Geographic location of breeding area influenced stopover patterns
        - East coast Ospreys spent 4 times as much of their fall migration in stopovers compared to spring
        - Western Ospreys had similar proportion of stopover days in fall and spring
- East Coast Ospreys departing and arriving on breeding areas earlier than Midwest and Western Ospreys could be related to availability of open water and thus food
    - Nesting sites primarily coastal with waters that rarely freeze
    - Midwest Ospreys must wait for frozen inland lakes/rivers to thaw
- Fall migration for east coast migrants longer because south-bound birds continue over land rather than flying more directly over sea
    - Could be because fall migration coincides with hurricane season, birds vulnerable over open water

NGSS

MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-ETS1-3: Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

24. **Marzluff, J., Delap, J., & Haycock, K. (2015). Population Variation in Mobbing Ospreys (*Pandion haliaetus*) by American Crows (Corvus brachyrhynchos). *127*(2), 266-270.**
- Mobbing behavior has strong learned component
    - Learn about novel predators by individual and social experience
- If identity of benign predators is learned, then variation in behavior is expected to occur between populations of mobber that differ in experience
    - Population-level variation in mobbing not reported
- In western U.S., American Crow vary in exposure to the fishing behavior of Ospreys
    - If crows can learn to ignore benign predators, then neighboring crow populations should differ in their reactions to Ospreys
    - Crows near water features should habituate to Osprey presence
    - Inland crows should innately mob Ospreys like they do to other raptors
    - All crows should respond strongly to Bald Eagles and Red-Tailed Hawks which regularly kill crows
- Combine field observations and controlled experiments to test hypotheses
- Mobbing and risk
    - Crows mobbed greater risk predators more than benign predators
        - Only 1 observation of crow mobbing Osprey

    - Risky behavior confirmed in experiment
        - Crows mobbed Ospreys less frequently and less vigorously
- Population variance in response to Osprey
    - In areas where Ospreys were regularly encountered, they were rarely mobbed
        - If Ospreys rare, mobbing more frequent
    - Engaged with equal intensity regardless of location
- Supports hypothesis that mobbing frequency and intensity are adjusted to the risk posed by predator
- Results consistent with selective habituation: a strong innate or learned predilection to a certain stimulus (fear and mob raptors in this study) decreases due torepeated encounters to stimulus
- Crows learn to associate individual and social experiences with rewards and punishment
    - This sensitivity is characteristic of group living birds in dynamic environments

<u>NGSS</u>

MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

25. Mestre, L., & Bierregaard, R. (2009). The Role of Amazonian Rivers for Wintering Ospreys (Pandion haliaetus): Clues from North American Band Recoveries in Brazil Between 1937 and 2006. *Studies on Neotropical Fauna and Environment, 44*(3), 141-147.

- Presents band recovery data from Ospreys banded in North America and recovered in Brazil between 1937 and 2006
    - Relates distances and time elapsed between banding and recapture
    - Discusses importance of Amazonian rivers too migratory Osprey populations
- 71 of the 90 individuals analyzed were banded as nestlings
    - 88 Ospreys recovered, all but one banded in 15 US states (mostly eastern coastal states)
    - 65 individuals shot
    - Of all recovered Ospreys, 68% were less than 3 years old
- Importance of Amazon
    - Most eastern US Ospreys winter in South America, 82% of Osprey recoveries from this study were in the Amazon
    - Ospreys usually spread out over a vast area where human population densities are low and pesticides are not widely used
    - Although 73% of Ospreys recovered in Brazil were shot, the number of recoveries after gunshots has decreased in the current decade (possibly due to a fear of punishment for illegal hunting)
        - Study does not specify why Ospreys are shot
    - Concludes that there are many Ospreys spread across the Amazon basin and the recoveries after gunshot represent a much lower percentage of the wintering population than in more densely populated areas
    - A large number of recoveries in Brazil were inland, near rivers

<u>NGSS</u>

MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.
MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

26. **Miller, M., Ewins, P., & Galloway, T. (1997). Records of Ectoparasites Collected on Ospreys from Ontario. Journal of Wildlife Diseases, 33(2), 373-6.**
    - Attempted to determine possible biotic factors contributing to reduced Osprey activity
    - Collected ectoparasites from nestlings and live trapped adults
    - Found lice intensity to be comparable to other diurnal raptors in southwestern U.S. (40% of nestlings)
    - 85% of nestlings had *Busseola fusca* (species of moth), all adults had *B. fusca*
    - 8 specimens of mites in each of the 3 nests

<u>NGSS</u>
MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.

27. **Monti, F., Duriez, O., Arnal, V., Dominici, J., Sforzi, A., Fusani, L., . . . Montgelard, C. (2015). Being Cosmopolitan: Evolutionary History and Phylogeography of a Specialized Raptor, the Osprey *Pandion haliaetus*. BMC Evolutionary Biology, 15, BMC Evolutionary Biology, 2015, Vol.15.**
    - Osprey is 1 of 6 bird species with almost worldwide distribution
    - Study aimed to clarify phylogenetic structure and elucidate taxonomic status
    - Currently, there are 4 subspecies of Osprey split on basis of morphometry and plumage characteristics
    - Conclusions
        - Genetic tree revealed 4 Osprey groups representing quasi non-overlapping geographical lineages (New World area, Indo-Australasian area, Western Palearctic area, and Asia)
        - Each lineage showed low internal genetic variability. Haplotypic and nucleotide diversity also weak
        - Despite low variability within each group, high number of nucleotide differences between the 4 clades
        - Diversification for each of the 4 groups dated between 0.14 and 0.27 Ma during Upper Pleistocene during a relatively short time period
            - New World group first to emerge, consistent with fossil records
        - Historical demographic reconstruction for each lineage suggests populations underwent stable trends or slight increases
            - New World - expansion about 10,000 years ago, consistent with recent fossils of Osprey in central Europe

        - Asia - only clade seeming to suffer some demographic decline. Could be due to small sample size.

NGSS
MS-LS4-1: Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.
MS-LS4-6: Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.
MS-ESS1-4: Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.

28. Ortega-Jimenez, V., Arriaga-Ramashashrez, S., & Alvarez-Borrego, S. (2011). Parental Infanticide by Osprey (Pandion haliaetus) During Nest Defense. Journal of Raptor Research, 45(1), 93-95.

- Parental infanticide is common in many avian species as a mechanism of brood reduction and as "accidental infanticides" during high stress events
    - Parental infanticide is an uncommon behavior in raptors
- Brood reduction in Ospreys is typically from sibling aggression, with parents contributing indirectly by disproportionately feeding the strongest nestling
- Authors document first reported occurrence of parental infanticide by an Osprey during a nest defense against two Common Ravens in Baja California, Mexico
    - One Osprey stayed on the nest while the other performed several aerial chases to displace the ravens. After an hour, following a long chase, the Osprey came back to the nest and seized its own nestling with its talons. It immediately flew away from the nest carrying its nestling and dropped it into the sea. The nestling was still alive during the fall because it was flapping its wings.
- Authors did not monitor nest success after observations to evaluate the value of the brood reduction
- Suggestions for why parental infanticide occurred:
    - Potentially reduce time for re-laying by the Osprey pair (consistent with theoretical models)
    - If the least vigorous chick was selected, it could contribute to reducing brood size and minimize cost of rearing other nestling
    - Minimize nest value for predators (minimal-loss strategy)
    - Accidental infanticide due to high stress
        - During high stress situations, Ospreys are known to display displacement aggression: fly off from nest, take pieces of nest material, and drop them onto the ground
        - Other displays of displacement aggression were not observed during the event
    - Nestling may have slipped from adult's talons due to its continuous wing flapping, causing its own demise

NGSS
No clear connection to NGSS.

29. **Siegel, R., Pyle, P., Thorne, J., Holguin, A., Howell, C., Stock, S., & Tingley, M. (2014). Vulnerability of birds to climate change in California's Sierra Nevada. Avian Conservation and Ecology/Ecologie Et Conservation Des Oiseaux, 9(1), Np.**
    - Long-term anthropogenic climate change may threaten bird populations through habitat change and prey availability
    - Investigated potential impact of climate change on breeding bird populations in the Sierra Nevada using the Climate Change Vulnerability Index (CCVI)
        - Assessed 168 species, including the Osprey
        - Used 2 different climate models with substantially different precipitation projections
        - Goals: identify individual species whose breeding populations are most likely to be jeopardized and assess patterns in the habitat associations of those species
    - The majority of species (65.5% and 74.4% for each projection) are not projected to be jeopardized substantially or benefited by climate change in the Sierra Nevadas during the next 50 years
        - Includes birds associated with foothill, sagebrush, and chaparral habitats
    - 24.4% and 17.3% are projected to experience increases in range or population
        - Includes birds associated with foothill woodland and chaparral habitats
    - 9.5% and 8.3% are projected to be moderately or extremely vulnerable
        - Includes birds associated with alpine/subalpine habitats – lack higher altitudes to shift range
        - Includes birds associated with aquatic habitats, like the Osprey
    - Birds tend to not be as vulnerable as other taxa because of their vagility and dispersal capacity
    - Osprey ranked as moderately vulnerable to climate change in the Sierra Nevadas

NGSS

MS-LS2-4: Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.

MS-ESS3-2: Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.

MS-ESS3-3: Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ESS3-4: Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.

MS-ESS3-5: Ask questions to clarify evidence of the factors that have caused the rise in global temperatures of the past century.

30. **Strandberg, R., & Alerstam, T. (2007). The Strategy of Fly-and-Forage Migration, Illustrated for the Osprey (*Pandion haliaetus*). Behavioral Ecology and Sociobiology, 61(12), 1865-1875.**
    - Predicts that fly and forage strategy during migration is favorable as a strategy and in combination with stopover behavior
    - Evaluated under what general conditions a fly and forage migration strategy, or a stopover strategy, or a combination of both, is optimal
    - Investigated possible existence of fly and forage migration strategy among Ospreys using field observations of the behavior of birds on migratory passage from Southern Sweden during 2 autumn and 2 spring seasons

- Conclusions
    - Fly and forage strategy is widespread and regular, and is often combined with stopover behavior, particularly during autumn migration
    - Females tended to stopover further north than males
        - Could be because females intensify their feather molt during earlier part of autumn migration
    - Ospreys do not tend to intensify foraging before/after daily travelling period

NGSS
MS-LS2-1: Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.
MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

31. **Sustaita, D., & Hertel, F. (2010). In Vivo Bite and Grip Forces, Morphology and Prey-Killing Behavior of North American Accipiters (Accipitridae) and Falcons (Falconidae). *The Journal of Experimental Biology, 213*(Pt 15), 2617-28.**
    - While Accipitridae and Falconidae feed on similar prey, they exhibit different hunting strategies
        - Falcons tend to pursue prey in open air at high speed, often in sustained chases, until they strike with feet to immobilize and sometimes kill
            - Tend to employ jaws by delivering powerful bites to the neck to kill
        - Hawks tend to ambush prey or engage in short chases of bursting speed to forcefully grapple victims with feet and talons
            - Rely on feet for prey dispatch
    - Study investigated mechanistic bases for differences in killing mode focusing on cross-sectional areas (PCSAs) and moment arms of digit flexors and jaw-closing muscles
    - Demonstrated differences in bite and grip forces between hawks and falcons that are consistent with their primary prey-killing modes and biomechanical capabilities
        - Falcons tend to bite harder than hawks
        - Hawks tend to grip with greater force than flacons
        - Greater diversity of species would be required to detect a statistical difference when accounting for phylogeny
    - Juvenile bite and grip forces were lower than adults
    - Bite forces were absolutely and relatively lower than seed-eating finches
    - In vivo bite force positively correlated with beak and head dimensions, but not significant when adjusting for body mass
    - Grip force positively correlated with hind limb dimensions, but not with body mass

NGSS
MS-PS2-1: Apply Newton's Third Law to design a solution to a problem involving the motion of two colliding objects.
MS-LS4-6: Use mathematical representations to support explanations of how natural selection may lead to increases and decreases of specific traits in populations over time.

Activity Idea

View PDF of gripping strength of bald eagles in Google Drive project folder. Students will be able to understand the concept of psi and the force of hawks, including Osprey, use when hunting prey. The PDF describes the Bald Eagles grip to be upwards of 400psi, 10 times stronger than the adult human. To get an idea of this, students can cut out one square inch of paper and carefully stack quarters on the paper on top of a scale until it measures one pound. Students can then balance the weight of the quarters on the back of their hand to full experience 1 psi. Now imagine it was 400 times this amount! Students can measure and graph their own psi force using a partially deflated basketball and a pressure gauge to compare their force to that of the Bald Eagle.

32. **Washburn, B., Martell, M., Bierregaard, R., Henny, C., Dorr, B., & Olexa, T. (2014). Wintering Ecology of Adult North American Ospreys. *Journal of Raptor Research, 48*(4), 325-333.**
    - Aim to describe various aspects of wintering ecology of North American Osprey via satellite telemetry
        - Determine duration of wintering period
        - Characteristics of wintering areas
        - Quantify space use and daily activity patterns
    - Arrival/departures and duration of wintering period
        - Arrived as early as July 31 and as late as December 4
        - Females arrived earlier than males
        - 100% fidelity to wintering site in this study
        - Overall, sex influenced duration of wintering period
        - Departed as early as January 10 and as late as April 7
    - Characteristics of wintering area
        - ranged in latitude from southern U.S. to southern reaches of South America
        - ranged in longitude from west coast of Mexico eastward throughout the Caribbean and the east coast of South America.
        - All wintering areas included at least 1 major water body
            - 50% wintered on rivers
            - 30% wintered on coastal areas
            - 19% wintered on lakes
        - Females wintered on river systems more
        - Males wintered on all 3 areas equally
        - Breeding region influenced type of water body
            - River wintering
                - East coast – Florida populations
                - East coast – Northeast populations
                - Midwest populations
            - All 3 body types with equal frequency
                - East coast – Midwest populations
                - Pacific Northwest populations
        - Wintered in forest dominated areas (50%) more than grasslands (6.3%) and residential areas (3.8%)
        - Wetland areas (13.9%) and agriculture areas (25%) also common

    - Forest and agriculture habitat most frequent habitat in males and females
- Space use
    - Ospreys made only short distance, local movements
        - No evidence that Ospreys shift their habitat or winter home ranges during wintering
    - Females
        - Home range size: 18.3 to 26.0 km^2
        - Core use area: 1.9 to 2.5 km^2
    - Males
        - Home range size: 2.2 to 14.5 km^2
        - Core use area: 0.7 to 0.9 km^2
    - Ospreys wintering on rivers had larger home ranges and were more oval shaped rather than circular
- Activity patterns
    - Diurnal activity patterns, mostly occurring between 1000 and 1600

<u>NGSS</u>
MS-LS2-2: Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.

33. **Zachos, F., & Schmölcke, U. (2006). Archaeozoological Records and Distribution History of the Osprey (*Pandion haliaetus*) in Central Europe. *Journal of Ornithology, 147*(4), 565-568. doi:10.1007/s10336-006-0080-6**
    - Presents overview of archeozoological records of Osprey in Central Europe using a database of vertebrate findings
    - Summarizes distribution and population status
        - Between the last glaciation and middle ages, only 12 known archeozoological findings, contrasted to over 1,000 sites with other bird species
        - Whole Pleistocene period – Osprey findings rare in Central Europe, Australia (no findings), and North America (7 found in Florida)
        - Gap of 4000 years in Osprey record from Central Europe
            - Taxon specific because other birds of prey regularly found
            - Suggests Ospreys not a common breeding bird in Europe 7,000 years ago
        - Distribution expanded in the following centuries, but declined around WWII with the use of DDT
        - Has made a remarkable comeback with better management and Osprey's use of artificial nesting sites

<u>NGSS</u>
MS-LS4-1: Analyze and interpret data for patterns in the fossil record that document the existence, diversity, extinction, and change of life forms throughout the history of life on Earth under the assumption that natural laws operate today as in the past.
MS-ESS1-4: Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.

Resources for Indian Education for All

In the future, WOW Staff intends to create Osprey themed lesson plans that would incorporate Essential Understandings from Montana's Indian Education for All initiative (https://opi.mt.gov/Educators/Teaching-Learning/Indian-Education). Select resources and activity ideas are presented here to help WOW staff further that goal. Before incorporating any ideas into lesson plans, there should be consultation with tribal representatives.

Resources – TEK Related

Linderman, F.B. (2012). Why the Kingfisher Always Wears a War-Bonnet. *Indian Why Stories*. Dover Publications.

Mason, L., et al. (2010). Time to Listen and Learn: Traditional Knowledge, Western Science, and Contemporary Resource Management.

Activity Idea

Students can learn about a different way of knowing from the perspective of Traditional Ecological Knowledge (TEK). Activities can begin by creating a Venn diagram to visualize the differences and similarities between scientific knowledge (SEK) and TEK. "Why the Kingfisher Always Wears a War-Bonnet" could be read to offer students an example of sense of place. Then, students can develop their own sense of place, practicing a core characteristic of TEK and gaining an understanding of the resources they have and share with others. Students can go outside and write down names of plants, animals, or other things they know about their natural world and how they relate to them. What do they hear, see or smell? Are surrounding man-made or natural? Are students separate from their surroundings or joined? After returning inside, Google Earth could be used to explore students' wider community of mountains, rivers, etc. What do students share with the plants and animals they wrote about earlier? How have we impacted those resources? Could that change students sense of place?

Resources – Climate Justice Related

Confederated Salish and Kootenai Tribes. (2013). *Climate Change Strategic Plan* (pp. 1-83) (Confederated Salish and Kootenai Tribes of the Flathead Reservation). MT.

National Congress of American Indians. (n.d.). Climate Change. Retrieved from http://www.ncai.org/policy-issues/land-natural-resources/climate-change

U.S. Environmental Protection Agency. (2019, February 05). Environmental Justice. Retrieved from https://www.epa.gov/environmentaljustice

Ward, B. (2016, May 6). Ospreys and Climate Change. Retrieved from https://www.yaleclimateconnections.org/2016/05/ospreys-and-climate-change/

Background Information

Ospreys are already impacted by human-caused climate change and are at risk to be impacted even more in the future. According to the Audubon Society, Ospreys are projected to lose 79 percent of their current summer range by 2080 due to climate change – only 60 years from now (https://www.audubon.org/field-guide/bird/osprey)! Ospreys are predicted to move further north as temperatures rise. It may be possible for some Ospreys to live year-round in places like Florida, but for most Ospreys scientists do not know whether there will be enough food or how higher run-off may affect fishing and survival of Osprey young. Ospreys have already been recorded returning earlier to their spring nesting sites. For the past several years, one citizen scientist in Virginia has been recording a return of 2-3 weeks ahead of schedule (Ward, 2016).

Like the Osprey, Native Americans are at risk of the negative consequences of climate change. Nearly all tribes live in areas susceptible to flooding and other extreme weather events, and work in economies that depend on resources easily affected by climate (National Congress of American Indians, n.d). Compared to white affluent communities in the United States, Native Americans are unfairly vulnerable to climate change despite contributing the least toward its causes. This is an example of an environmental justice case. Environmental justice means that everyone, regardless of race, color, origin, or income, is fairly treated and meaningfully involved in environmental decisions and policies (U.S. EPA, 2019). Environmental justice also concerns fairness in how the burdens of climate change and other human activity are shared across different communities and populations. Although many decisions made by U.S. policy makers have a significant impact on Native American land, water, and other resources, they have not been meaningfully involved in the decision-making process, causing an environmental *injustice*.

To confront the challenges of climate change, the Confederated Salish and Kootenai Tribes of the Flathead Reservation created a comprehensive Climate Change Strategic Plan in 2013. The Strategic Plan details interviews with elder Tribal members (pg 41-48). Through traditional knowledge and their deep sense of place, Tribal elders have made important climate change observations. These oral histories provide valuable insight from their ancestors, which can be used as a tool to address climate change.

Activity Idea

Students can learn the detriments of climate change on both the Osprey and the Confederated Salish and Kootenai Tribes. Students can identify consequences of climate change currently happening in their own community, such as wildfire season or melting glaciers, by exploring Climate Smart Missoula's Summer Smart webpage (https://www.missoulaclimate.org/summer-smart.html). How do these consequences impact not just humans, but plants and wildlife? After listening to Ward's audio on Ospreys and Climate Change, students should be able to identify how the bird is impacted. Ospreys did not help cause climate change, but how are they being affected by it? Is it in a good way or a bad way? Is this fair for them? Move on to explain the concept of environmental justice to students. Use pictures or videos to give examples. Who is disproportionately impacted by climate change or other environmental hazards? Students could be divided into groups and read Tribal elder interviews from The Confederated Salish and Kootenai Tribes' Climate Change Strategic Plan. What evidence of climate change is being witnessed by Tribal elders? How does this impact their way of life? Is this an example of environmental injustice? What surprises students?

Birds of the PEAS Farm

Humans have rapidly transformed a large portion of Earth's natural habitat into agricultural land with pervasive consequences. As of 2005, 40% of Earth's surface was dedicated to food production in the form of cropland and pastureland. Agricultural land now rivals our forests as the largest terrestrial biome on the planet. Some consequences of contemporary industrial agriculture include: water pollution, soil erosion and nutrient loss, decline in biodiversity and natural habitat, release of atmospheric carbon, and extensive use of pesticides. The ramifications are so great that modern agriculture is parallel with global climate change as an anthropogenic threat to biodiversity.

When managed properly, farms can be a place for biodiversity to thrive. The PEAS Farm is a diverse habitat of trees, shrubs, flowers, crops, and open space analogous to ecological habitat in nature. The farm is an important corridor between Rattlesnake Creek to the east, the grassy hills to the west, and the mountains beyond. It is also home to a plethora of wildlife, including dozens of species of birds. From June through September 2018, Environmental Studies MS Candidate, Kat Olson, collected data on bird species from different areas of the farm. The data is presented here as part of a self-guided tour to highlight the significance of the PEAS Farm to our feathered friends.

Thank you to Justin Theurer (Environmental Studies BA 2019) for his beautiful photo contributions and to Jessie Hampton (Environmental Studies MS 2019) for her kind patience and graphic design assistance!

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American Goldfinch, ***Spinus tristis***

The American Goldfinch is the strictest vegetarian bird in the world, eating only seeds.

Unlike most birds, the American Goldfinch is a late season nester, nesting in July and August when plants have produced their seeds.

The song of an American Goldfinch is a high pitched series of twitters and warbles. When it's in flight, listen for rapid *po-ta-to-chip* call.

Find me in my favorite spot among the sunflowers or hiding in other flower stands.

American Robin, ***Turdus migratorius***

Listen for a familiar *cheerily-cheerup-cheerio* song to identify this permanent resident.

The American Robin may be one of the most adaptable birds, occurring in all forest habitat types, woodlots, swamps, tundras, and human dominated open spaces like yards and parks.

The American Robin has incredibly keen eyesight, detecting the smallest of movements from worms beneath the soil.

Find me singing on tree branches or digging up insects among crop rows and in the grass.

Brewers Blackbird, ***Euphagus cyanocephalus*** (left)
European Starling, ***Sturnus vulgaris*** (top)
Brown-headed Cowbird, ***Molothrus ater*** (bottom)

The Brewers Blackbird has a strong appetite for insects, helping with pests around the farm. Look for a yellow eye and listen for a short, metallic *conk-la-ree*!

All European Starlings in North America are nearly genetically identical after being introduced in 1890 from only 100 birds. They mimic calls of other birds; don't let them fool you!

Brown-headed Cowbirds are a "brood parasite." They lay eggs in the nests of other bird species, who then raise the chick as if it were their own. This has caused population decline in several species of other birds.

Find these birds among crop rows, in grassy areas, and perched on utility poles.

Calliope Hummingbird, *Selasphorus calliope*

Although it is the smallest bird in North America at 3 inches tall, the Calliope Hummingbird travels 5,000 miles every year to breed in Mexico before returning to the mountains of the northwest.

Hummingbirds get their iridescence from small air bubbles on the surface of their feathers. As light hits the feather, some light reflects off the surface and some light travels through the air bubble to reflect off the inner surface. When the light wavelength matches the thickness of the air bubble, it is magnified and results in intense color.

Find me sipping nectar from flower stands around the farm and from blossoms in the orchard.

Eastern Kingbird, *Tyrannus tyrannus*

Tyrannus means “tyrant, despot, or king.” The Eastern Kingbird will aggressively defend its territory against much larger predators, flashing its hidden crown of yellow, orange, or red feathers when doing so.

When wintering in the Amazon, Eastern Kingbirds travel together in flocks and eat a fruit-filled diet. During mating season in North America, they aggressively defend their territory against other kingbirds and eat only flying insects.

Find me in the orchard or on the ground in bare fields and grassy areas during early spring. Listen for flustered, high pitched sputtering ending on a buzzy *zeer*.

Northern Flicker, ***Colaptes auratus***

The Norther Flicker is a year-round resident commonly seen and heard around Missoula. Listen for a rhythmic *wicka wicka* call.

Although the Northern Flicker is a woodpecker, it spends most of its time on the ground hunting for ants and beetles – its main diet. It can extend its long tongue two inches beyond its beak to get the job done!

Find me perched on branches, among crop rows, and out in the open on the grass.

Great Blue Heron, *Ardea herodias*

The PEAS Farm is an important habitat corridor for many bird species, including the Great Blue Heron. It can be found roosting high in trees and hunting fish along Rattlesnake Creek to the east.

Despite reaching a height of 4.5 feet, the Great Blue Heron only weighs 5-6 pounds due to its hollow bone structure. This is a feature that all birds have.

Great Blue Herons have great night vision thanks to a high percentage of rod-type photoreceptors, allowing them to hunt day and night.

Find me flying over the farm with my neck tucked in and long legs outstretched behind me.

House Finch, ***Haemorphous mexicanus***

The House Finch is not naturally red! It gets its color from pigment proteins found in plants it eats and therefore, can be red, orange, or yellow.

The House Finch used to range only across the southwest, but is now widespread across the country after it was illegally released by pet shop owners in 1940 New York.

Listen for a long, warbling song composed of short notes and ending on a lengthy slurred *veeerr.*

Find me perched on trellises and fences singing my familiar song.

Killdeer, *Charadrius vociferus*

The Killdeer got its name from its raucous, repeating *kill-deer* call.

The Killdeer will pretend to have a broken wing to lead predators away from its nest on the ground. To prevent its nest from getting stepped on, the Killdeer will fluff up its feathers, display its tail over its head, and make a charge at hoofed animals to frighten them.

Find me in bare fields during springtime or hanging out in the grass during summer.

Lazuli Bunting, *Passerina amoena*

First-year male Lazuli Buntings arrive at breeding grounds without a song of their own. They create their own songs by listening to other males around them, rearranging notes and syllables.

Along their migration route, Lazuli Buntings will stop in southern Arizona, southern New Mexico, and northern Mexico at “molting hot-spots”. They spend 1-2 months molting their feathers before completing their journey south.

Listen for a repeated warble of sharp, squeaky notes.

Find me in flower stands around the farm and in raspberry bushes.

Pine Siskin, ***Carduelis pinus***

Pine Siskins are well adapted to cold. To survive chilly nights, they boost their metabolic rate 40% higher than other birds of their size, despite putting on half as much winter fat.

Pine Siskins can store 10% of their bodyweight in seeds inside their esophagus. This fuels their metabolism when temperatures reach subzero.

Listen for their unmistakable call, a harsh, rising *zhreeeeeeeeet*.

Find me in the orchard or on other trees and bushes around the farm.

Red-tailed Hawk, *Buteo jamaicensis*

The raspy, descending shriek of the Red-tailed Hawk is famously used in nearly all Hollywood films, even if there's a different raptor species onscreen.

Sharp-shinned Hawk, *Accipiter striatus*

The Sharp-shinned Hawk was one of the many species that plummeted in population during the DDT era (1940s-1972). Their numbers have since rebounded!

Bald Eagle, *Haliaeetus leucocephalus*

Bald Eagles often steal freshly caught prey from raptors and mammals, instead of hunting their own food.

Golden Eagle, *Aquila chrysaetos*

Golden Eagles are some of the fastest and most adept flyers of North American raptors. They can reach speeds of 200mph during a dive.

Find these raptors soaring over the PEAS Farm. Use binoculars to get a good look at their colors and patterns to tell them apart.

Song Sparrow, *Melospiza melodia* (left)
House Sparrow, *Passer domesticus* (right)

Song sparrows are common across the U.S. but have vast regional differences. In the Pacific Northwest, the Song Sparrow is dark and heavily streaked like the one pictured here. In Alaska's Aleutian Islands, Song Sparrows are one third longer and weigh twice the average!

Song Sparrow songs begin with a few short, sharp notes and ends with a trill or buzz. Trills of various tempos can be heard in the middle.

House Sparrows are the most common bird in the world. Listen for a simple series of *chirrup* notes.

Find these birds hanging out all over the farm; in crop rows, flowers, the orchard, or perched singing by the chickens!

Tree Swallow, ***Tachycineta bicolor*** (left); **Barn Swallow,** ***Hirundo rustica*** (top); **Northern Rough-winged Swallow,** ***Stelgidopteryx serripennis*** (bottom)

Many swallow species migrate to the northwest during the warm summer months, including the Violet-Green Swallow, Bank Swallow, and Cliff Swallow (not pictured).

Because of their streamlined shape and long pointed wings, swallows are some of the best aerialists of the bird world.

Swallows are insectivores, eating only insects captured during flight.

Find swallows catching insects above the crop rows during the early hours of the morning.

Yellow Warbler, *Dendroica petechia* (right)
MacGillivray's Warbler, *Oporornis tolmiei* (top)
Wilson's Warbler, *Wilsonia pusilla* (bottom)

The Yellow Warbler sings a familiar springtime song. Listen for a distinct *sweet-sweet-sweet I'm-so-sweet!*

The MacGillivray's Warbler is a secretive bird, found mostly in dense understory. Birders are usually on the look-out for this elusive bird!

Populations of Wilson's Warbler are in steep decline due to habitat loss in migratory pathways and breeding grounds. They require shrubby thicket habitat near streams.

Find the Yellow Warbler in the orchard, flower stands, and raspberry bushes. **MacGillivray's Warbler** and **Wilson's Warbler** spend time in the native garden—important habitat adjacent to Rattlesnake Creek.

Cedar Waxwing, ***Bombycilla cedrorum***

The brightly colored Cedar Waxwing is a frugivore, eating almost exclusively fruit! It can become intoxicated and sometimes even die from eating fermented berries.

The Cedar Waxwing is a very social bird and is rarely seen by itself outside the flock.

Listen for a wispy, high-pitched *zeeeee* to identify a cedar waxwing.

Find me in the orchard or in raspberry bushes looking for something sweet to eat.

Western Meadowlark, *Sturnella neglecta*

Montana's state bird is often heard singing from the grassy hills just west of the PEAS Farm. Listen for a fluty, R2D2-like song that begins with a series of slow whistles and ends with a rapid gurgle.

Western Meadowlarks build their nests on the ground, often with a grass roof or entrance tunnel several feet long. Watch your step on your next hike!

Western Meadowlarks have strong muscles around their beak that they use for feeding. By inserting their beak into soil or bark and forcing their jaw open, they access insects that other birds can't.

Find me flying over the farm or singing from the nearby hills.

Downy Woodpecker, *Dryobates pubescens* (left)
Hairy Woodpecker, *Dryobates villosus* (right)

The Hairy Woodpecker and its lookalike, the Downy Woodpecker, have similar feather patterns, calls, and ecologies. To tell them apart, look for a "downsized" beak as a sign for a Downy Woodpecker.

Like other woodpeckers, the Hairy and Downy Woodpeckers don't sing songs. To communicate they drum on trees and other objects.

Because of its small beak and size, the Downy Woodpecker hammers on weed stalks, reeds, and thin branches to eat insect larvae inside.

Find me in the orchard drumming away or making a sharp *peek* call.

PROPOSAL BIRD DETERRENT TECHNOLOGY

Prepared for

ADRIANNE DONALD
Director
University Center

LARRY MCELRAVY
Associate Director
University Center Building Services

Prepared By

KAT OLSON
Sustainability Coordinator
ASUM Sustainability Center

CONTENTS

EXECUTIVE SUMMARY

As urban areas are continually built in and around landscape features that are also vital habitat for wildlife, planners have a responsibility to mitigate and minimize adverse impacts. It has been documented that urban areas can play an important role in conservation work by providing green spaces, but we must be cognizant that inviting wildlife to use these spaces may be hazardous to them as they interact with human structures. The University Center (UC) is an example of this circumstance. Certified Wildlife Habitat landscaping provides a sufficient space for wildlife to find refuge and is a great asset to conservation work on campus. However, there are several problem areas at the UC that are inherently hazardous to birds and have triggered costly wildlife-human conflicts for the UC as a result. This document was prepared by the ASUM Sustainability Center for UC Building Services to consider various options in mitigating those areas, while keeping maintenance, feasibility, and cost in mind.

Based on the research and findings of this report, it is recommended that the UC:

1. Install a DIY version of the Bird Crash Preventer on the Branch Center Windows, and on cafeteria windows if proven successful, to prevent bird deaths due to window collisions. **Cost:** $137.00.

2. Install StealthNet as a permanent fixture on the loading dock roof to prevent birds from nesting. **Cost:** $93.65 plus additional hardware costs.

3. Install Irri-Tape above loading dock doors to deter birds from entering the building. **Cost:** $31.00 for 100' roll, $99.75 for 500' roll.

4. Paint the penthouse mechanical room white to make the wall less attractive to woodpeckers. **Cost:** approximately $100.

5. Install Irri-Tape on the corners of the room to deter woodpeckers from drumming. **Cost:** $31.00 for 100' roll, $99.75 for 500' roll.

INTRODUCTION

Landscape features that promote human livability, such as our rivers or vast forests, are also important in sustaining wildlife populations. Urban areas are often built in or near these landscape features to increase accessibility and capitalize on natural aesthetics, typically without full consideration of the impact to wildlife habitat. Urbanization has led to large scale habitat loss and fragmentation with no sign of slowing. According to the United Nations, 68% of the world's population is expected to live in cities by 2050, a 15% increase from today (2018). To accommodate that growth, cities are sprawling outward on a global level with Missoula following the same trend. This presents us with both a challenge and an opportunity to identify the balance between human demands and the needs of wildlife in urban centers.

Cities should play a key role in conservation work to mitigate their environmental impacts. Urban wildlife habitat can provide refuge or connectivity between natural habitat through the creation of parks, gardens, and green spaces (U.S. Forest Service, n.d.). It can also be an accessible avenue for people to connect with nature, raising support for conservation in general. The University Center (UC), located on the University of Montana (UM) campus, is a leading example of urban conservation work through the use of native landscaping around its perimeter. UC landscaping is certified Community Wildlife Habitat, providing adequate food, water, shelter, and space to wildlife (City of Missoula, n.d.). This habitat attracts many species of birds. I have witnessed cedar waxwings, American robins, black-capped chickadees, sparrows, and northern flickers among the vegetation there. This naturalized landscape also contributes to positive student experiences by providing work or learning opportunities and by preserving features of natural areas that attract students.

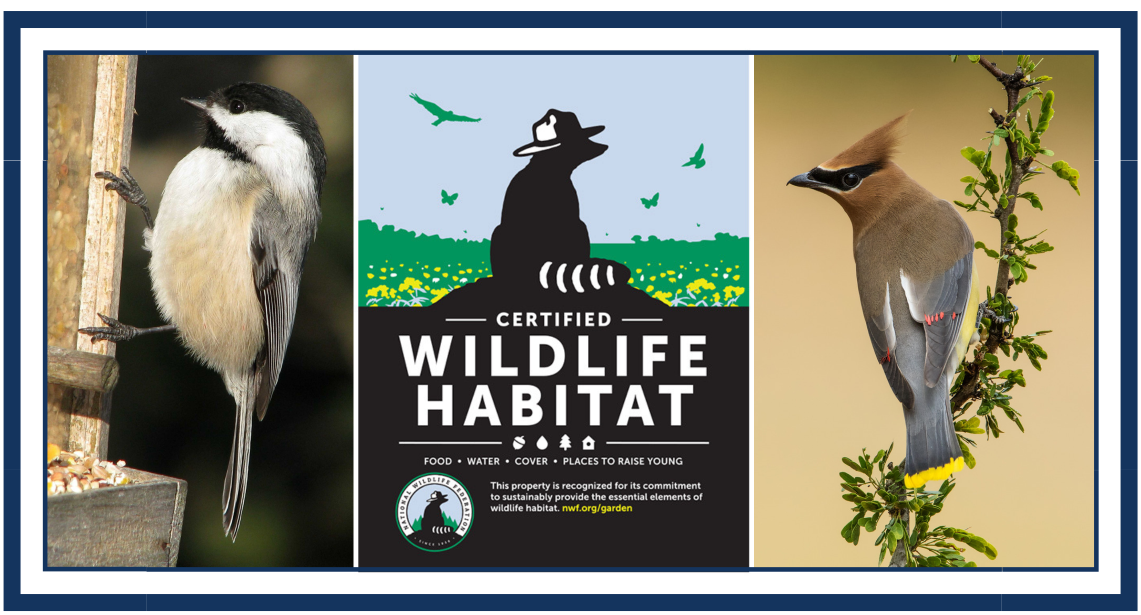

Figure 1. Black-Capped Chickadee, Certified Wildlife Habitat Sign, and Cedar Waxwing

Creating an inviting space for wildlife, however, has its consequences. There are several problem areas at the UC that are inherently hazardous to birds and have triggered costly wildlife-human conflicts for the UC as a result. Larry McElravy, UC Building Services Associate Director, has been consulted to appropriately identify problem areas and possible mitigation techniques. Briefly, those problem areas are: the Branch Center windows, the UC loading docks, and the penthouse mechanical room on the UC roof. This document offers a detailed description of the issues these areas present to both birds and the UC, the best available products on the market that can be used for mitigation, and recommendations for selecting products that would be the most effective and economically feasible. Although research on mitigating bird-human conflicts is scant and novel, all products and recommendations are based on the best information that could be found.

Figure 2. Flowers in the UC Garden

Adopting mitigation measures would continue the UC's benchmark work in campus conservation and set yet another precedent for the campus community. The UC has been a leader and role model in various sustainability initiatives, due in part to the excellent working relationship with students and in part to the consistent support from dedicated staff. Furthermore, mitigation techniques for the UC windows in particular will provide a learning and engagement opportunity. Upon the adoption of mitigation techniques, the ASUM Sustainability Center will create educational posters to hang inside the Branch Center and an informative plaque that can be presented beneath the windows outside among the UC's landscaping. By educating campus on how to not only create space for wildlife, but to minimize hazards that may unintentionally follow, the UC will continue to showcase its sustainability leadership.

PROBLEM AREA 1: BRANCH CENTER WINDOWS

Figure 3. UC Branch Center Windows

Birds frequently fly into the Branch Center windows and die because the windows reflect the surrounding landscape. The cafeteria windows are also deadly, although birds fly into them much less often. According to Larry McElravy, the cafeteria windows are more exposed to the elements and therefore tend to be much dirtier, buffering reflections. The aesthetic of the Branch Center windows has been a point of contention during prior conversations on managing this problem area. The windows of the Branch Center were intended to be a window into student life, where onlookers can see students working inside and students can view campus from within. If mitigation strategies on the Branch Center windows are successful, mitigation should be considered for the cafeteria windows as well.

Branch Center Window Dimensions: 10’6” by 37’ 6”

Recommendations

It is recommended for the UC to adopt the DIY concept of the Bird Crash Preventer, as it is one of the most effective bird deterrent options, offers minimal visibility impairment, requires little maintenance, and is affordable with a low cost of $137.00.

Background

Windows are unseen barriers, visually deceiving to birds and humans alike. For humans, window collisions inevitably end in embarrassment and sometimes, in injury. For birds, window collisions are nearly always fatal. Windows reflect open flying space and habitat that birds do not perceive as a mirror. Unfortunately, windows are a ubiquitous building material, especially in urban infrastructure. They cause the death of up to one billion birds annually in the United States alone, which is second only to the common house cat (Bayne, Scobie, and Rawson-Clark, 2012). Not only do bird-window collisions impact an immense number of birds, but they impact a considerable amount of bird species. Approximately 30% of North American bird species have suffered from window collisions, including some Threatened and Endangered (T&E) species like the Kirtland's warbler and the yellow-billed cuckoo – a migratory species that has been documented to visit Montana in June and July (Klem, 2014; U.S. Fish and Wildlife Service, n.d.). Nearly 11% of the species of concern "at risk" for T&E listing in the State of Montana have also suffered window collisions: northern goshawk, Le Conte's Sparrow, evening grosbeak, pileated woodpecker, varied thrush, loggerhead shrike, and Cassin's finch (Montana Natural Heritage Program and Montana Fish, Wildlife, & Parks, n.d.). The continued sprawl of urban centers and use of glass as a building material increases the risk of impact to birds. Bird-window collisions are a significant, and frankly underappreciated, anthropogenic danger to birds, one with sustainability and conservation implications.

There are several factors influencing the risk of a bird-window collision. In particular, studies show that birds are more likely to collide with windows if the building size is large, has a high window area, is in a low-level urbanization area, and has a surrounding green space (Hager & Craig, 2014; Hager et al., 2017; Bayne et al., 2012). Furthermore, Bayne et al. have demonstrated that older, versus newer, neighborhoods have higher collision rates, as well as residences with bird feeders. Many of these factors are present at the UC. The UC is a big building with several large windowed areas. The Branch Center windows face and reflect the Oval, a large green space. Campus is directly adjacent to undeveloped land to the east and to the west, an older neighborhood with mature vegetation – suitable habitat for many bird species. Lastly, landscaping surrounding the UC is certified Community Wildlife Habitat, providing adequate food, water, and shelter to wildlife (City of Missoula, n.d.). Although the UC's efforts to become Community Wildlife Habitat certified should be viewed as a positive thing, there is an unintentional ramification of creating that space in an area seemingly at high risk for bird-window collisions. We have an moral obligation to mitigate this issue. Without some mechanism of deterrence, birds will surely continue to die from window collisions at the UC as they seek refuge.

There are a variety of tools on the market for preventing bird-window collisions that are cost effective, minimally impact aesthetics, and do not impede the two-way visibility of UC windows. The products included in this section have been tested and recommended by The American Bird Conservancy (ABC). ABC tests various products for their effectiveness in deterring birds from windows, then provides ratings and recommendations (n.d.). They test products to offer more resources for homeowners and architects addressing conservation in their lives, and also for the growing number of cities, counties, and states adopting bird-friendly architectural guideline legislation. This trend toward sustainable, bird-friendly design encouraged the U.S. Green Building Council LEED program to initiate Pilot Credit 55: Bird Collision Deterrent (n.d.). Should the UC choose to pursue LEED Certification in the future, a collision deterrent mechanism could be counted as a 1 credit criteria.

Technology on the Market

Bird Crash Preventer

Figure 4. Bird Crash Preventer

Description: The Bird Crash Preventer (http://stores.santarosanational.com/) is a curtain of fishing line spaced 3” apart with 90% effectiveness as tested by Dr. Daniel Klem Jr., according to the Bird Crash Preventer website. The fishing line appears to be either clear or green in all product pictures. Curtain rods are ¾” metal tubes that are held by two brackets above and below the window. This is the best product for visibility in and out of the UC, however Bird Crash Preventers are only available in 3’ and 4’ wide models up to 84” long. This same concept could be DIY constructed relatively cheaply. Fishing line is cost effective and durable, lasting several years out in the elements.

Installation: Screw in brackets 3" apart along the top and bottom of the window. Tie fishing line vertically to each bracket and replace as needed.

Cost Estimate:

- 37'6" window length x 12 = 450" window length
    - 450"/3" = 150 lines of vertical line, each 10'6" tall
    - 150 lines of vertical line x 2 = 300 brackets and 300 screws
- 10'6" window height x 12 = 126" window height
    - 150 lines x 126" height = 18,900"
    - 18,900"/12 = 1575' of line needed

Item	Quantity	Cost	Total
High impact fishing wire, 400 yards	2	$8.50 on Amazon	$17.00
Black angled brackets, 50 pack	6	$15.90 on Amazon	$96.00
Black screws, 100 pack	3	$8.00 on Amazon	$24.00
TOTAL			$137.00

Table 1. Bird Crash Preventer Cost Estimate

Acopian Bird Savers a.k.a Zen Wind Curtains

Description: Zen Wind Curtains (www.birdsavers.com) are vertically hung olive-colored paracord, spaced 4.25” apart, that have been tested to be over 90% effective in preventing bird strikes (Klem, 2011). Paracord is a long lasting, cost effective material requiring little maintenance, and could be a great solution for the UC. As depicted in Figures 6 and 7, the University of Chicago has installed Zen Wind Curtains with success.

Installation: Zen Curtains are attached using screws and clamps just above the window on the outside. They can be left hanging a few inches above the bottom of the window or can be clamped down to present a straighter line.

Cost Estimate: Acopian Bird Savers are made to order and have free shipping. Two Bird Savers could be ordered with the 126” height and 216.75” wide dimensions, which would cost $94.00 each, or $188.00 total. Alternatively, there are DIY instructions on the website and would be relatively easy to make and install (https://www.birdsavers.com/buildyourown.html). Paracord, clamps, and screws can be purchased in town inexpensively.

Dimension "A" is the distance from the horizontal paracord to the top of the glass.

Figure 5. Acopian Bird Savers

- 37'6" window length x 12 = 450" window length
    - 37'6" of horizontal paracord needed
    - 450"/4.25" = 106 lines of vertical paracord, each 10'6" long
- 10'6" window height x 12 = 126" window height
    - 106 lines x 126" height = 13,356"
    - 13,356"/12 = 1,113' of vertical paracord needed
- 37'6" + 1,113' = 1,150.5' paracord needed

Item	Quantity	Cost	Total
Paracord, 1000 ft spool, olive green	2	$44.80 on Amazon	$89.60
Black cable clamps, 100 pack	2	$7.59 on Amazon	$15.20
Black screws, 100 pack	2	$8.00 on Amazon	$16.00
TOTAL			$120.80

Table 2. DIY Acopian Bird Savers Cost Estimate

Figure 6. Acopian Bird Savers at the University of Chicago, outside view

Figure 7. Acopian Bird Savers at the University of Chicago, inside view

SX-SFH Horizontal Bird Safety Film

Figure 8. Horizontal Bird Safety Film

Description: Horizontal Bird Safety Film (https://www.decorativefilm.com/solyx-sx-bsfh-bird-safety-film-59-or-70-wide-2) is made of a clear, weather and scratch resistant polyester film and has a lifespan of 7 years. The stripes are 1/8" wide and the space between each stripe is 1". This is a significantly more expensive deterrent option that would would not last as long as the Bird Crash Preventer or Acopian Bird Savers.

Installation: Clean area, create wetting solution (soap and water), and cut film to size. Remove liner from film and spray exposed adhesive with wetting solution. Spray glass with wetting solution and apply window film. Squeegee to remove air bubbles.

Cost Estimate: Rolls are only sold in 58" and 70" wide, but the Branch Center windows are 126" wide. A roll of each width would have to be purchased to properly fit. I rounded up the window length by several feet to accommodate for mistakes during cutting and install.

- $30.76 per running foot for a 58" roll width x 40' window length = $1,230.40
- $36.89 per running foot for a 70" roll width x 40' window length = $1,475.60
- TOTAL: $2,706.00

ABC Bird Tape

Figure 9. ABC Bird Tape

Description: Bird tape is a translucent, weather resistant tape applied to the outside of the window. It is 75% effective and lasts up to 4 years.

Installation: Clean area, cut length of tape, peel off backing, and apply. If bird tape is applied horizontally, space 2” apart; if vertically or diagonally, 4” apart. Bird tape can be removed with a razor blade or putty knife.

Cost Estimate:

- Rolls = $17.95 for a 50' (600") length
- 37'6" window length = 450" window length
    - 450"/4" = 113 lines of vertical tape, each 10'6" tall
- 10'6" window height = 126" window height
    - 113 lines x 126" height = 14,238" of tape neededl
- $14,238"/600" = 24 rolls needed
- TOTAL: $430.80 for 24 rolls of ABC Bird Tape

Problem Area 2: Loading Dock

There are two loading docks in the UC where birds, likely pigeons, have chosen to nest in the roof. Not only is this a nuisance, but it has created a health and safety problem. Birds periodically fly into the UC when the dock doors are open, gaining access to food preparation areas, cafeterias, and people at work. If not caught immediately, birds could excrete droppings, which have been linked to more than 60 human diseases (Ziddiqi, 2006). Additionally, UC staff has to spend time and resources capturing and safely removing the birds. The birds nesting in the dock roof should be prevented from nesting there again, which will hopefully decrease the amount of birds flying in through open dock doors. This is a common issue with loading dock roofs and can be successfully resolved by installing netting to create an impenetrable barrier. Larry has previously looked into netting as a solution. A deterrent should also be installed above loading dock doors to make the area unwelcoming, further discouraging birds from flying through the open doors.

Roof dimensions: 18.5’ by 20.8’
Deterrent space: 22” tall space between overhang of building and dock door covering; building overhangs 21” and the dock cover protrudes 29” from wall.

Figure 10. Loading dock roof and doors

Recommendations

It is recommended to install StealthNet as a permanent solution to prevent birds from nesting underneath the loading dock roof. Considering that it will require no maintenance after installation, will last longer than 10 years, and is comparable in price to other mitigation techniques, it is the best bang for the UC’s buck. Irri-Tape seems to be a promising bird deterrent and, although there is no indication of how long this product lasts in the elements, is recommended to be installed above dock doors as a deterrent for birds entering the building (Harding, Curtis, and Vehrencamp, 2007). If a more permanent solution is desired, the scare rods could prove to be an effective technique, as they are visually similar.

Technology on the Market

Bird Barrier Stealth Net

Description: StealthNet (https://birdbarrier.com/stealthnet-overview) is 100% effective in preventing bird entryway, lasts for 10 years or more, and is the most cost-effective and permanent net system on the market, according to the Bird Barrier website. Because it will be installed underneath a roof, protected from the elements, it is likely to last longer than 10 years. StealthNet is constructed with steel and durable polyethylene twine and includes tensioned cables that attach directly to the application site. Colors come in black, beige, and white to minimize visibility of net. Pre-cut and custom dimension sizes are available to order. The 2-inch standard netting should suffice to deter most bird species, including pigeons.

Installation: Installation requires 7 various hardware pieces, all available to purchase on the Bird Barrier website. UC building maintenance will have to assess the infrastructure of the roof to identify which hardware would be needed.

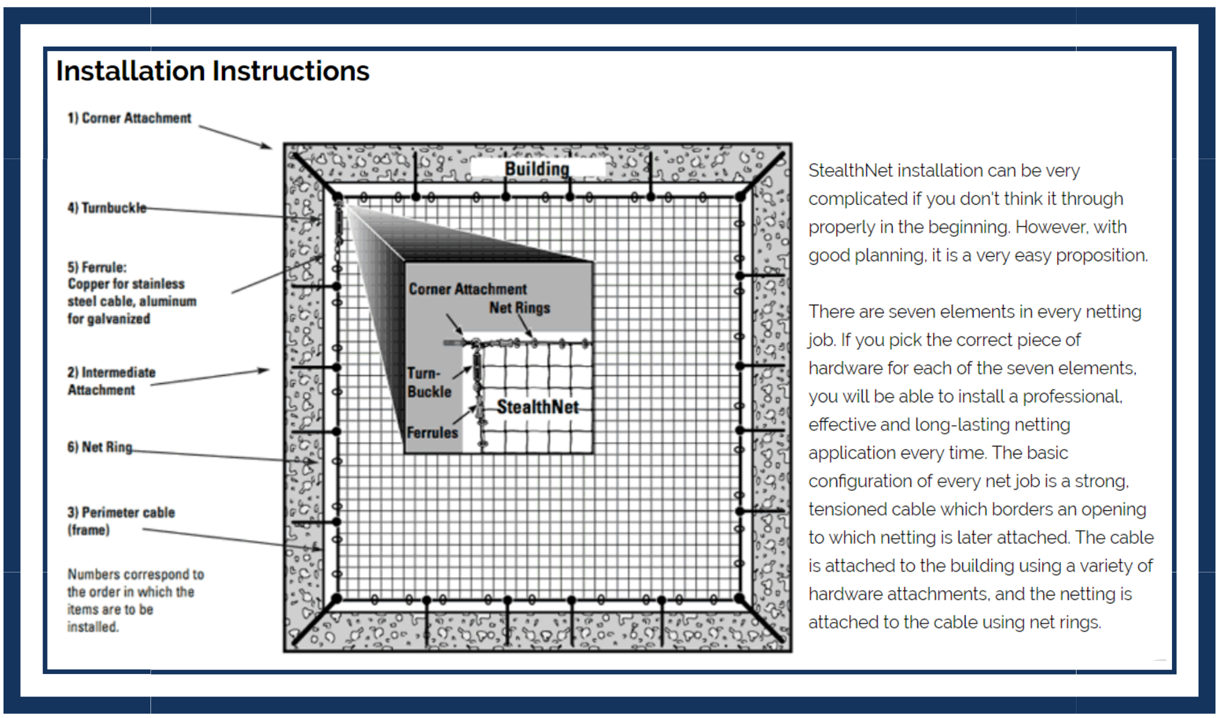

Figure 11. StealthNet Installation

Cost Estimate: A white, 2-inch standard, 25’ x 25’ StealthNet is $93.65. Further discussion with Larry is needed to appropriately assess hardware costs.

Bird Barrier Optical Gel

Figure 12. Bird Barrier Optical Gel

Description: Optical Gel (https://birdbarrier.com/optical-gel.html) is a small, round dish filled with citronella, peppermint oil, agar, and beeswax. The dishes visually appear similar to fire or smoke, smell bad to birds, and are sticky to touch - all factors that birds find displeasing. They are 2.5" in diameter and ¼" tall, weather resistant, and last 2-4 years. This could be an effective deterrent for nesting birds, as most Amazon reviews are 5 stars and describe great success with this product, even with woodpeckers.

Installation: Remove covers from dishes and glue, silicone, magnetically stick, or zip-tie to the affected area. For woodpeckers, place dishes 6" apart for optimum effect, depending on use of area.

Cost Estimate: $95.00 per 24 pack on Amazon.

Bird-X Bird-Proof Gel Repellent

Figure 13. Bird-X Bird-Proof Gel Repellent

Description: Birds are deterred from landing on sticky, invisible gel repellent that lasts up to one year (https://bird-x.com/bird-products/gels-liquids/bird-proof-gel/). This repellent can withstand all weather: rain, wind, snow, sun, and heat. Many reviews discuss smaller birds becoming entrapped and flailing around for hours until humans put them to death, which is also expressed as a warning on the cartridge. Because of this, bird-proof gel should be used as a last resort. The main ingredient is polybutene and is not toxic according to the Safety Data Sheet. One cartridge equates to 10 linear feet; 12 cartridges cover 120 linear feet.

Installation: Apply with a standard caulking gun. For wide surfaces, apply beads 2" apart starting 5" in from the outside.

Cost Estimate: $54.44 for 12 cartridges or $17.28 for 3 cartridges on Amazon

Bird Repellent Reflective Scare Rod

Description: Wind motion is used to scare and deter birds from adapting to an environment. These 15" long reflective rods can be hung from the UC overhang above the dock doors to prevent birds from entering the UC. For best results, it is recommended to use these in direct sunlight in a breezy area, which may be a limiting factor to their success in this problem area. There is a major complaint in Amazon reviews of the string attachment breaking from the wind. Many users recommend fishing line as a stronger material.

Installation: Install eye-hook screws above dock doors for rods to hang from.

Cost Estimate:

Item	Quantity	Cost	Total
Scare Rods, 6 pack	2	$13.95 on Amazon	$27.90
Eye hook screws, 100 pack	1	$8.99 on Amazon	$8.99
TOTAL			$36.89

Table 3. Reflective Scare Rod Cost Estimate

Figure 14. Reflective Scare Rod

Irri-Tape

Description: Irri-Tape (https://bird-x.com/bird-products/visual-scares/irri-tape/) is holographic bird tape using wind motion to scare and deter birds from adapting to an environment. It is visually reflective, but also makes a flapping noise in the wind. It is made of polyester, is 2" wide and is available in 100' and 500' rolls. The 100' roll comes with 8 brackets for installation and the 500' roll comes with 36.

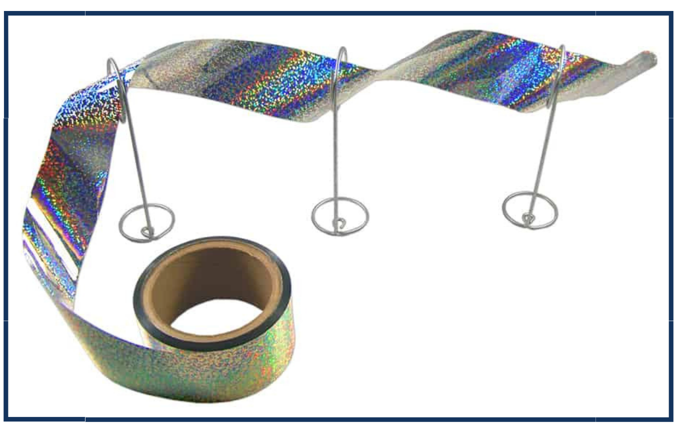

Figure 15. Irri-Tape

Installation: It is recommended to install brackets above dock doors at intervals of 12' to 15'. Thread Irri-Tape horizontally through the brackets periodically twisting to form a spiral. Tie off or clamp ends securely, then tie ribbons of ~15" every 2' to hang down.

Cost Estimate: $31.00 for 100' roll, $99.75 for 500' roll

Reflect-a-Bird Deterrent

Description: Wind motion is used to scare and deter birds from adapting to an environment. The spinner can be installed above each UC dock door in addition to the scare rods, or by itself. It is made of aluminum and plastic, is weatherproof, weighs one pound, and is 11 x 11 x 12”.

Installation: Glue, screw, or tie down to an area.

Cost Estimate: Can be purchased from local hardware stores for approximately $40.00 to $50.00 per spinner x 2 = $80.00 to $100.00.

Figure 16. Reflect-a-bird Deterrent

Problem Area 3:
Penthouse Mechanical Room

On the roof of the UC there is a mechanical room containing 2 HVAC units. Woodpeckers consistently peck into the wall, which is primarily made of Stucco material, and through the insulation until they hit drywall. Larry has tried a fake owl deterrent to no avail, as UC staff has to constantly repair drumming damage. There is concern of this causing damage to the interior of the room's wall as well, which could compromise the HVAC units. The type of bird causing this destruction is probably the Northern Flicker, as it is the likeliest woodpecker species to cause building damage (Jasumback et al., 2000). Because damage appears to be isolated at the corners of the room, the entire room may not have to be mitigated, saving on costs.

Dimensions: 9' 6" x 25' 6" x 27'; top 5" is metal flashing, bottom 10" is roof rolling up

Figure 17. Penthouse mechanical room woodpecker damage

Recommendations

The first step to mitigate this problem area is to make the area less attractive to woodpeckers. The penthouse is currently painted a natural reddish color, but if painted white it could help deter woodpeckers while aesthetically matching the roof. Because Irri-Tape has been seemingly successful in at least one study, it is recommended to be installed on the corners of the room. Although the idea of installing nest boxes and working with the woodpeckers is attractive and also seems to be a promising solution, it is not recommended due to the sensitivity of the HVAC units.

Background

To many, woodpeckers are pesky pests that are more than a noise nuisance. Although this is an older estimate from the late 1990s, woodpeckers cause $300 in damage to affected homes on average and cost millions of dollars in property damage across the nation (Harding, et al. 2007). The reasons woodpeckers drum holes into buildings are numerous: to declare territory, attract a mate, gouge a nest or roost site, or to forage for insects. Larry has identified a history of nesting inside the penthouse wall, which is likely an enticing nest spot. The stucco material on the outside of the penthouse is soft and easily penetrable, insulation would be warm from the trapped heat radiating from the HVAC units, and the building is well secluded from predators.

Figure 17. Northern Flicker

Only a handful of studies have attempted to test the effectiveness of woodpecker deterrent techniques. Belant, et al. tested the use of methyl anthranilate on wood for deterring woodpeckers, which is a product that has been used to deter birds from tailing ponds and industrial impoundments (1997). Their tests concluded that woodpeckers were unaffected, because they do not ingest wood when foraging or excavating. Harding, et al. tested 6 common techniques typically used by homeowners: Prowler Owls, Irri-Tape, Bird Pro Sound System, Scary Eyes, suet feeders, and roost boxes (2007). None of the techniques proved to be completely successful, but the most promising technique was the use of Irri-Tape, which eliminated damage in 50% of trials. The study also noted that houses painted a bright color like white or pastel, as opposed to a natural color, received significantly less damage from woodpeckers. Jasemback, et al. suggests completely netting off the area with a ¾" net, an effective mechanism for deterrence, however this will be a hefty expense for a building as large as the penthouse (2000). They also suggest installing nest boxes over nest holes to provide an alternative site while preventing damage. Notably, this method was tested by Harding et al. with promising results, but the sample size was too small to be considered significant (2007).

Technology on the Market

White Paint

Description: Structures of a brighter color seem to be less attractive to woodpeckers. Painting the penthouse white would be a great first step.

Cost Estimate: Exterior paint can be purchased for less than $100 at a local store, and the UC may already have paint. Follow-up with Larry is required.

Northern Flicker Nesting Box

Description: This nesting box has dimensions perfectly suited for northern flickers at approximately 2' long with a 2.5" diameter hole, similar to the dimensions recommended by Jasemback et al (2000). All 40 reviews on the product remark great success with 5 stars, however the shipping cost is a major expense. This could be a great construction project for a student, which would significantly reduce costs. Link to product is under Photo References.

Installation: Install over current nesting holes after repair

Cost Estimate:

Item	Quantity	Cost	Total
Nest Box	2	$28.00 on Etsy	$56.00
Shipping	2	$55.95	$111.90
TOTAL			$167.90

Table 4. Northern Flicker Nesting Box Cost Estimation

Figure 18. Northern Flicker Nesting Box

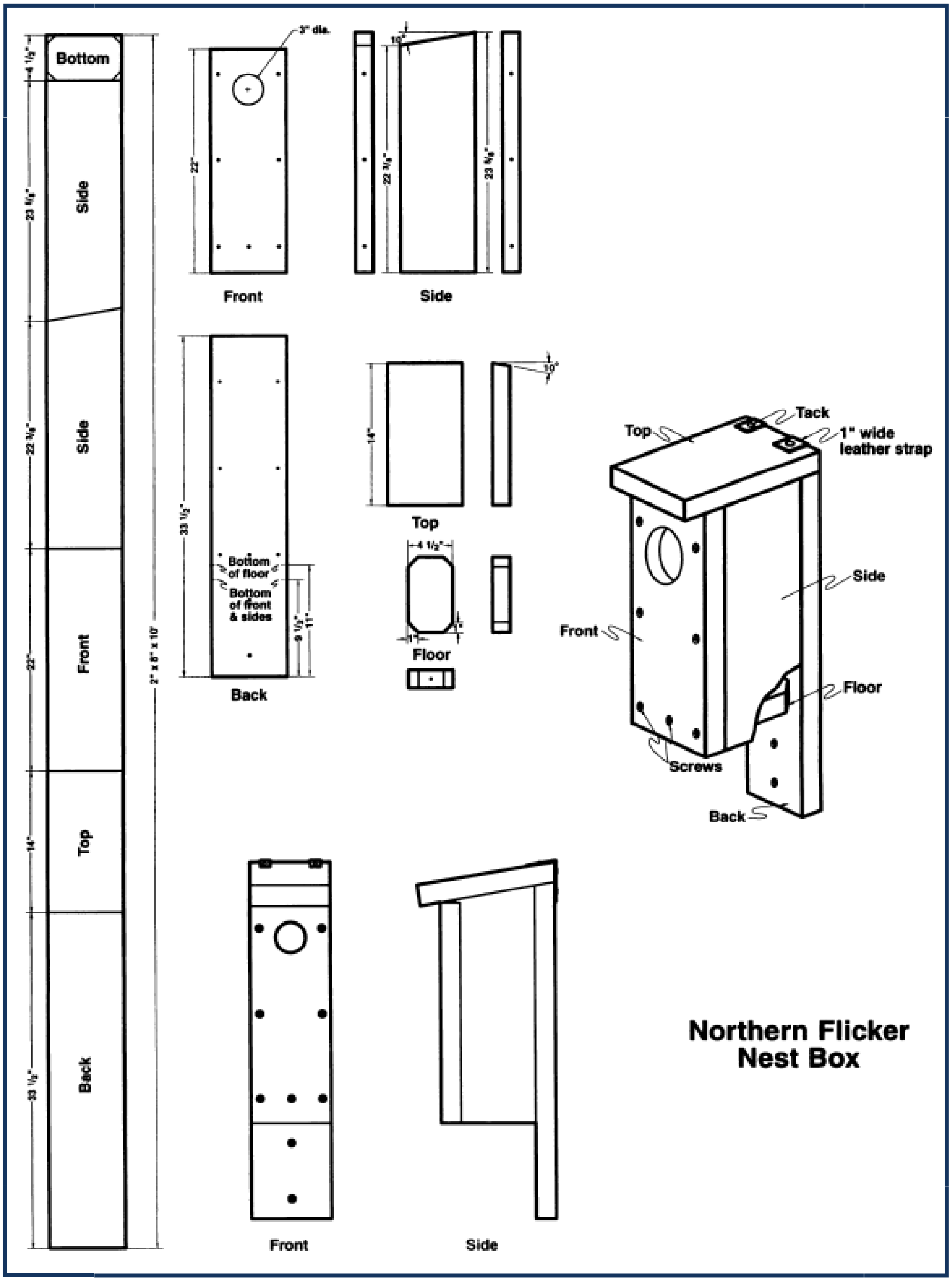

Figure 19. Northern Flicker Nesting Box Blueprint

Irri-Tape

Description: Irri-Tape (https://bird-x.com/bird-products/visual-scares/irri-tape/) is holographic bird tape using wind motion to scare and deter birds from adapting to an environment. It is visually reflective, but also makes a flapping noise in the wind. It is made of polyester, is 2” wide and is available in 100’ and 500’ rolls. The 100’ roll comes with 8 brackets for installation and the 500’ roll comes with 36 brackets.

Installation: It is recommended to install brackets above penthouse corners and thread vertically downward through the brackets periodically twisting to form a spiral. Tie off or clamp ends securely, then tie ribbons off approximately 15” every 2’ to hang down.

Cost Estimate: $31.00 for 100’ roll, $99.75 for 500’ roll

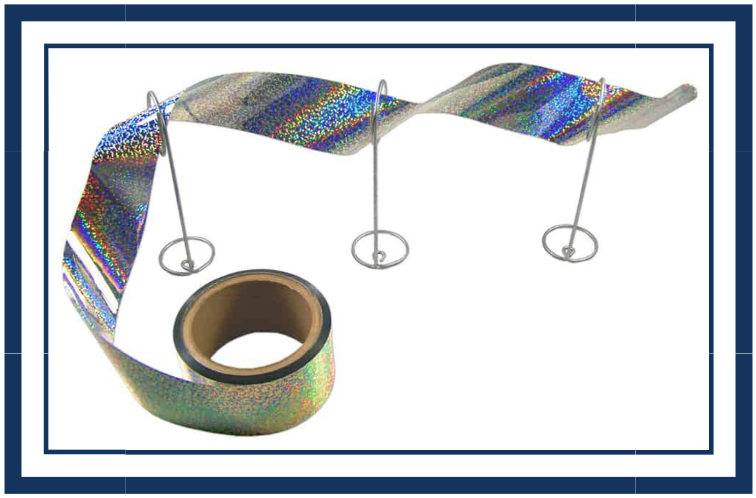

Figure 20. Irri-Tape

Bird-X Bird Stop Liquid Bird Deterrent

Description: When applied to a surface, Bird Stop Liquid emits a potent, bitter smell to deter birds. Methyl Anthranilate is the main ingredient, an acutely toxic chemical used as a pesticide (SDS). When applied per instructions, risk is minimal. There is no indication how long this product will last or how often it should be applied. It comes in a 1-gallon container. Many reviews are poor and report having to apply 2-3 times to see desired effect. Of note, some reviews mentioned they were applying to structures at a 1:99 mix ratio, which is the ratio for applying to gardens and lawns and may be why product reviews are poor. Link to product is under Photo References.

Installation: Mix one part deterrent with 1 part water for buildings and structures. Apply with hand sprayer across the penthouse.

Cost Estimate: $83.00 per gallon with Amazon Prime.

Figure 21. Bird-X Bird Stop Liquid Bird Deterrent

4 the Birds Transparent Bird Repellent Liquid

Description: This transparent liquid creates a tacky surface that deters birds from roosting or landing. Main ingredient is polybutene, the same ingredient in the Bird-X Gel Repellent. This is a new product with only two reviews; one review saying it worked well and the other said it does not. There is no indication of how long this product lasts. Link: https://bird-x.com/bird-products/gels-liquids/4-the-birds-repellent-liquid/.

Installation: Seal porous surfaces and clean surfaces prior to application. Do not dilute. Apply with hand sprayer.

Cost Estimate: $56.92 for 1 gallon.

Figure 22. 4 the Birds Transparent Bird Repellent Liquid

In Summary

To mitigate adverse impacts to birds inherently caused by UC infrastructure, the ASUM Sustainability Center recommends the installation of the best available bird deterrent technology on the market. Recommendations were considered based on required maintenance, feasibility of installation, cost, and effectiveness.

Based on the research and findings of this report, it is recommended that the UC:

1. Install a DIY version of the Bird Crash Preventer on the Branch Center Windows, and on cafeteria windows if proven successful, to prevent bird deaths due to window collisions. **Cost:** $137.00.

2. Install StealthNet as a permanent fixture on the loading dock roof to prevent birds from nesting. **Cost:** $93.65 plus additional hardware costs.

3. Install Irri-Tape above loading dock doors to deter birds from entering the building. **Cost:** $31.00 for 100' roll, $99.75 for 500' roll.

4. Paint the penthouse mechanical room white to make the wall less attractive to woodpeckers. **Cost:** approximately $100.

5. Install Irri-Tape on the corners of the room to deter woodpeckers from drumming. **Cost:** $31.00 for 100' roll, $99.75 for 500' roll.

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